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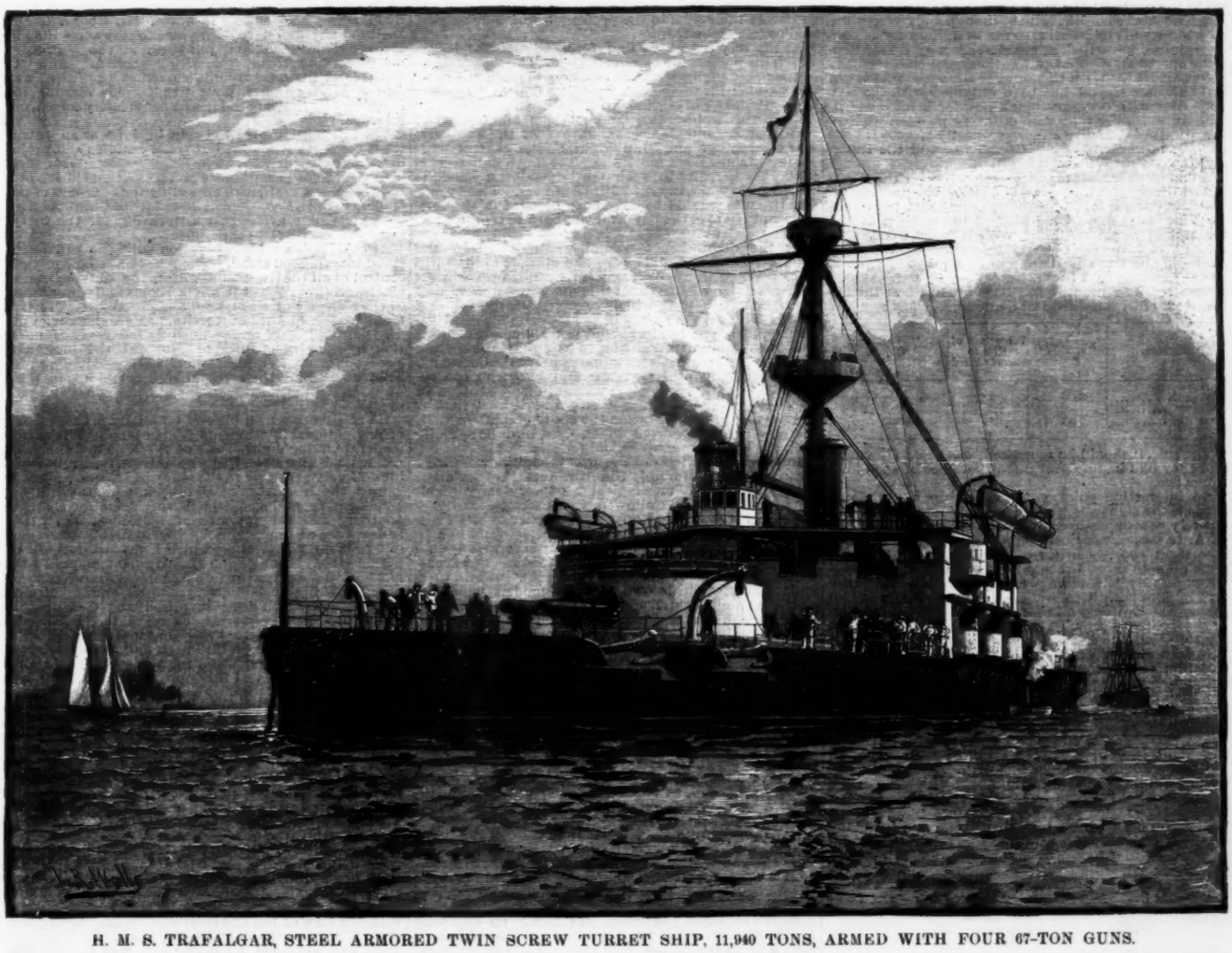
H. M. S. TRAFALGAR.

THE gunnery trials of this new and powerful ship of war, launched at Portsmouth in 1887, and now shortly to be commissioned for active service, took place on February 22, outside the Warner lightship. The Trafalgar, designed by Messrs. Barnes & Morgan, of the construction department of the Admiralty, is a vessel of 11,940 tons displacement, 345 ft. long, 73 ft. broad, and drawing 27 ft. 6 in. of water, built of steel, having two screw propellers, with engines of 12,000 indicated horse power, and has cost £863,000 for hull and engines. Her side armor plating is 16 in. to 20 in. thick, the breastwork armor 14 in. to 18 in., and her turrets 18 in. The turret guns are four 67 ton breech-loading rifled, and she carries eight 5 in. rifled guns, eighteen quick-firing guns, and four mortars, with six torpedo tubes. The speed of this ship is 16·50 knots an hour; her bunkers carry 1,200 tons of coal, and she can steam 6,500 miles with that supply of fuel.

The Trafalgar may be described as an enlarged and improved Dreadnought. She differs from the class of ships named after admirals, not only in the increased depth and longitudinal area of her vertical armor, but in the fact that, as in the case of the Dreadnought, she carries her main armament of four 13½ in. 67 ton guns mounted in pairs in a couple of turrets built along the middle line of the ship, instead of in barbettes similarly disposed. The change in the mounting of the guns, with the results of experience, has made it possible to introduce various modifications and improvements in the hydraulic loading gear, which is not only better placed in consequence of the less confined spaces in which it works, but is simpler and much easier to handle and control.—*Illustrated London News.*



H. M. S. TRAFALGAR, STEEL ARMORED TWIN SCREW TURRET SHIP, 11,940 TONS, ARMED WITH FOUR 67-TON GUNS.

FRENCH men of science have produced artificial emeralds by fusing silica, alumina, and glucina with traces of oxide of chromium, with acid molybdate of lithia at a temperature of 600° to 700° for fifteen days.

THE NEW MAGAZINE RIFLE.

COLONEL C. G. SLADE, commandant at the Hythe Musketry School, gave an interesting lecture lately to the Aldershot Military Society on "Modern Military Rifles." Though dealing principally with the changes in tactics which would be necessitated by the arm, he gave the following interesting table, showing the general features of the arms now adopted by the different civilized powers.

An examination of the table shows that France alone has a weapon equal to the English arm in the number of rounds contained in the magazine, while its mechanical features are decidedly inferior, and its weight greater. It will be seen that all nations have very much reduced the caliber, and most of the powers have fixed upon one of from 0·303 in. to 0·315 in., that of England being the smallest of any, with one of 0·303. Most of the powers have also adopted the box system of magazine, France alone among great nations having a tube magazine. This form has many disadvantages; the loading is slow, and the balance of the weapon alters at every shot. This, to a certain extent, is true also of the box system, but as in this case the supply of cartridges is concentrated near the mass center of the weapon, the alteration is not so great. The box magazines are of two types, that most favored being a fixed steel box situated in front of the trigger guard. This is filled by a filler made of thin steel containing five cartridges, and the magazine can thus be charged at one operation.

	Rifle.	Weight.	Caliber.	Magazine.	Rounds
		lb. oz.			
Austria	Mannlicher.	10 2	0·315	Fixed box.	5
America (Navy)	Lee.	.....	0·433	Detachable.	5
Belgium	Mauser.	9 8	0·310	Fixed box.	.....
China	Lee.	.....	0·433	.....	5
Denmark	Believed to have adopted the Lee.	.....	.....	.....	.....
France	Lebel.	9 4	0·315	Tube.	8
Germany	Mauser.	9 8	0·310	Fixed box.	5
Italy	Vetterli.	10 10	0·409	Fixed box.	5
Norway and Sweden	No definite conclusion yet arrived at.	.....	.....	.....	.....
Portugal	Not settled.	.....	.....	.....	.....
Russia	Not settled.	.....	.....	.....	.....
Spain	Not finally settled.	.....	.....	.....	.....
Switzerland	Vetterli.	10 10	0·109	Fixed box.	6
Turkey	Mauser.	.....	0·433	Tube.	8
England	Lee-Mitford.	9 6	0·303	Detachable.	8

England and America, the two great manufacturing nations, have agreed in adopting a weapon with a detachable magazine, the invention of a Scotchman named Lee, now resident in the United States. It has been improved in this country very considerably and is now in all probability the best military weapon in existence. One great advantage of the detachable magazine is that if one gets damaged on service it can easily be replaced, and another is that troops defending a position can be supplied with any number of spare magazines ready filled, which is equivalent to increasing indefinitely the effective capacity of the magazine.

Though the last power to adopt a magazine rifle, we may congratulate ourselves that our position has enabled us to thoroughly thrash the matter out, and not, as did Germany and Austria, waste millions of money in magazine rifles of a large caliber only to be replaced in a few months by new weapons. The old Martini-Henry was in many respects an inefficient weapon, the bullet was much too short, in spite of the fact that Whitworth many years before had proved by a most extensive series of experiments that a rifle bullet should be somewhat more than three times as long as its diameter. This ratio has, we believe, been adopted in all the new rifles, and the pitch of the rifle has at the same time been quickened, thus insuring that the point of the bullet shall maintain its direction at long ranges. It is interesting to note in this connection that at the siege of Alexandria several of the eighty-ton gun shells fired by the Inflexible were found afterward on shore

with their points toward the ships, thus showing that the rifling of the guns was insufficiently quick to preserve the parallelism of the axis of the shot. This decrease in the pitch, combined with the high velocity with which the bullet leaves all the new arms, has, however, been accompanied by several serious difficulties which it has taken an immense amount of experiment and trouble to overcome, and even yet it is doubtful if they have been entirely surmounted. To enable the bullet to take the quick rifling at these high velocities, something harder than lead is required. Whitworth, indeed, in one extreme case, where a shot was fired from a rifle with one turn in an inch, used a ball of hardened steel machined to fit the bore, and with this weapon some very interesting results were obtained. For this reason the bullets of all the modern small-bore rifles are coated with a shell of hard metal. The French use nickel or German silver, and we have tried steel. But the difficulties are aggravated by the use of the smokeless powders, now undergoing experiment all over the world. Many people will be surprised by Colonel Slade's statement that the fouling of the weapon caused by ordinary black powder is a positive advantage; but so it is. The fine, black, greasy deposit acts as a lubricant, and greatly assists the passage of the bullet along the barrel. With the new smokeless powders, however, there is no such deposit, and the friction is so great that particles of lead are stripped off the bullet, causing metal fouling, and in some cases the steel or nickel coating has been completely stripped off and left in the weapon. In spite of this, however, Colonel Slade holds that black powder is doomed, as the fouling becomes excessive in hot and dry climates, and a higher muzzle velocity than 1,850 to 1,900 ft. per second cannot be obtained even with compressed powder without excessive pressures in the chamber. Of the smokeless powders none seem entirely satisfactory up to the present; the most promising is probably Sir Frederic Abel's cordite, which, though not giving quite as good results as Nobel's, so far as uniformity is concerned, has, nevertheless, stood some very severe temperature tests without alteration, and its stability seems assured. With this powder a muzzle velocity of 2,350 ft. per second has been obtained with the new rifle, that with ordinary black powder being 1,830 ft. The Swiss Hebler rifle, with ordinary powder, we may remark, is said to give a muzzle velocity of 1,900 ft., the caliber, however, being but 0·295 in., and the rifling making one turn in about 790 ft.

A remarkable feature of the new magazine rifle when fired with ordinary powder is that a shot fired point-blank at 300 yards is a foot above the mark aimed at, the rise being due to the kick of the weapon at the moment of firing. Aiming with it point blank at a man's breast, the man would be struck by the shot, supposing he was anywhere within a range of from 50 to 450 yards, so that the trajectory is very flat. At long ranges very fair practice has been obtained, as the following results, obtained last September, show:

Distance.	Number of Hits.	Percentage of Hits to Rounds Fired	Object.
2,000 yards.....	181	48	Four companies in quarter column standing.
2,400 "	109	29	
2,800 "	104	18	

The rifle, it should be remarked, was new to the men, and they had had no previous experience of such long range fire.

An interesting point not touched upon by Colonel Slade is the sight adopted for the new rifle. This is an entirely new departure, and is the invention of Major G. A. Lewes, of the Northamptonshire regiment. The fore sight consists of a rectangular block of metal, which is split down the middle, the streak of light seen through this slit taking the place of the ordinary point. This slit, therefore, is not intended to be looked through, but simply aligned with the object aimed at in the ordinary way. The block in which it is cut being sufficiently massive, there is no danger of the slit being knocked out of line, and the sight is capable of standing any amount of rough usage. The back sight consists of a hinged flap and a sliding bar. This bar has the upper edge beveled and a square notch cut in the middle, from the center of which there runs down vertically a fine white line. This notch is of such a size that when accurate aim is taken the block forming the fore sight just fills it, and the white slit in this fore sight forms one continuous line with the white line of the back sight. Should the aim be too high, the block of the fore sight will appear before the general line of the bar of the back sight, and if too low, there will appear a gap between the top of this bar and the block of the fore sight. It is said that these sights are equal in practice to those of a match rifle, and it is, therefore, to be hoped that with the new weapon the British soldier will regain his reputation for cool and accurate marksmanship.—*Engineering.*

JAMES WATT.

JAMES WATT AND THE APPLICATION OF SCIENCE TO THE MECHANICAL ARTS.*

By ARCHIBALD BARR, B.Sc.

IT would appear to be the chief distinctive characteristic of the nineteenth century that it is the age of applied science. The ancients were perhaps our superiors in literature, in art, and in philosophy, for though in all departments of thought and action continual progress must be made, still the most noble individual works in literature and in art, and the most far-reaching departures in philosophy, belong to long past times. The science of mathematics has been the growth of centuries, and mechanics, astronomy, and mathematical physics have grown with its growth. Those who rank to-day as the greatest musicians the world has seen are men of a past time. Physics and chemistry and geology have made marvelous progress during this century, but though these sciences may rank with astronomy as worthy, for their own sakes, of the devotion of the noblest minds, yet it is their application to the material wants of man that is to-day the most potent incentive to their study and the chief cause of their growth and diffusion. The sciences of medicine and surgery have no doubt undergone an almost complete change in method and an unprecedentedly rapid development since this century began, and with them the science of biology, in all its branches, has grown from small beginnings. Still the conditions of life to-day are vastly more in contrast with those of last century in the material environment of man than in any other aspect.

Works which were produced ages ago still remain the grandest creations of the human mind and hand, in the realms of literature and of art, but few, if any, of the inventions of our forefathers remain in use. Even those connected with the most necessary processes in preparing clothing to cover, and food to nourish us, have entirely changed. The distaff and spinning wheel alike are superseded, and the millstone, which may be regarded as the last relic of the age of stone, and which only ten years ago held its place as almost the only contrivance for the grinding of corn, may be looked upon to-day as a thing of the past, which must soon find its only place in historical collections.

Mechanical arts have necessarily been practiced in all ages, and have developed and expanded through the centuries, but that which is the distinctive feature of the arts of the present is that those which have come down to us from ancient times have been entirely changed in method, and greatly extended in scope, by the aid which science has given them; and the growth of scientific knowledge has given rise to new arts, which could not even have been dreamt of by our forefathers. In any retrospect of this modern development of the mechanical arts, and of the aid which science has given to them, we cannot fail to be led back to the genius of James Watt as the fountain head in which the stream of progress had its source. With Watt, engineering, as we know it, may be said to have begun. His life must therefore be full of lessons for those who inherit the rich fruits of his labor, and especially for those who are to devote their lives to the profession which he may be said to have founded.

At the very outset we find foreshadowed the lesson which his life has for us as engineers. The grandfather of the great engineer was a teacher of mathematics and navigation; his tombstone describes him as "Thomas Watt, Professor of Mathematics in Crawfordsdyk." Of his two sons, John was a land surveyor and teacher of mathematics, and James, the father of the engineer, was a carpenter and shipwright, and a general merchant. James Watt must therefore have inherited—if there is heredity in such matters—all the elements which go to make the successful engineer. Theory and practice may be said to have been blended in the very flesh and blood of the boy who was born in Greenock in 1736.

At the time when Scotland was agitated by the Stuart rebellion of 1745, we get a glimpse of the early life of Watt, whose labors were destined to work a change in the conditions of life more widespread and beneficent than that which any political revolution could effect. We see a boy of the most fragile constitution, enduring all the hardships and ridicule which his weakness brought upon him in the playground, and the no less severe trials of a dunce in the schoolroom. But like many others, young and old, who are accredited dunces, Watt was simply a human being in an uncongenial and unsuitable environment. When, at the age of fourteen, he began the study of mathematics, his powers soon asserted themselves, and he speedily took the lead among his school fellows.

In reading the lives of the great engineers, nothing strikes one more forcibly than the fact that in all or almost all cases a mechanical bent very early manifested itself, and was allowed free exercise. A home workshop has afforded an essential part of the early training of most of those who have afterward risen to greatness in engineering. In Watt's case we have no exception to this rule. From childhood he was accustomed to work with his hands, to make his own toys, and to work out his own ideas in models which he contrived and constructed. His father provided him with a bench and a smith's fire, and his mother encouraged him in the use of his pencil. What better early training could there be for the future engineer? I fear that in these days of long school hours and cram, when much the same tools are used to shape the young mind, of whatever stuff it may be made and for whatever sphere of action it is intended, few Watts are likely to be produced. So expert did Watt become in manual work, that we are told that it became a byword among his father's journeymen that "Jamie had gotten a fortune at his finger ends." Nor did he neglect reading and study. All books that came in his way were eagerly read, and, as far as his opportunities allowed, he studied natural philosophy, chemistry, and other sciences before he was fifteen years of age.

His father's business, which it was originally intended that he should follow, had suffered reverses, and besides the youth's tastes went beyond the work of a common carpenter; it was therefore arranged that he should become a mathematical instrument maker, and with this end in view he went to Glasgow at the age of eighteen to learn the trade. He found no one who could instruct him in the art, but he got employment with a small tradesman, who repaired drawing instruments, fiddles, and spectacles, and sold fishing tackle. In all such work Watt was at home, and especially perhaps in the fishing tackle branch of his master's business, for he was as a boy an enthusiastic angler. But there was little chance among such surroundings of his learning much that would lead to future success in life.

He had made the acquaintance of Dr. Dick, professor of natural philosophy in the university, and on his advice, and bearing a letter of introduction from him, Watt started for London in the following year, his journey occupying a period that would now suffice for a voyage to New York and back. After considerable delay Watt secured a place, paying twenty guineas, and his labor, for a year's instruction. He was already so expert with his hands, and so apt in learning anything of a mechanical nature, that one year sufficed for his apprenticeship. During this time he contrived to earn some small amount by getting up early and working on his own account before he went to the shop. His work was, however, carried on in constant fear of the press gangs, and kidnappers, because, as he himself has said, "If I was carried before my lord mayor, I durst not avow that I wrought in the City, it being against their laws for any unfreeman to work, even as a journeyman, within the Liberties!"

His hard work told upon his constitution, and suffering from "violent rheumatism," "a gnawing pain in his back," and "weariness all over his body," he returned to Greenock, bearing with him a stock of tools, materials of which to make others, and a work on the construction and use of mathematical instruments. His whole future life was overshadowed by dyspepsia and sick headaches, and what may have been only the natural effect of this, he lived in chronic despondency. Long afterward he wrote to his partner Boulton, who lay ill in Cornwall, and complained of lowness of spirits: "There is no pitch of low spirits that I have not a perfect notion of, from hanging melancholy to peevish melancholy. You must conquer the devil when he is young." And not only from within but from without difficulties and often despair overshadowed him, and the smallest difficulty or reverse worried and vexed him beyond measure. He must indeed have had a good heart beneath it all, when he could make and maintain so many close friendships. Dr. Robison has written of him: "I have seen something of the world, and am obliged to say that I never saw such another instance of general and cordial attachment to a person whom all acknowledged to be their superior."

It happened that at the time Watt returned to Scotland, a valuable collection of astronomical instruments had been bequeathed to the university by a Scottish merchant long resident in Jamaica; and we find Watt writing from Glasgow to his father in Greenock, under date October 25, 1756: "I would have come down today, but there are some instruments that are come from Jamaica, that Dr. Dick desired that I would help to unpack, which are expected to-day." The minutes of a university meeting held on the following day contain the statement that "several of the instruments from Jamaica having suffered by the sea air, especially those made of iron, Mr. Watt, who is well skilled in what relates to the cleaning and preserving of them, being accidentally in town, Mr. Moor and Dr. Dick are appointed to desire him to stay some time in town to clean them, and put them in the best order for preserving them from being spoiled." And six weeks later the same records show that "a precept was signed to pay James Watt five pounds sterling for cleaning and refitting the instruments lately come from Jamaica."

Watt next attempted to begin business as an instrument maker in Glasgow, but trade customs and prejudices were in his way. The Corporation of Hammermen would not permit one who was neither the son of a burgess, nor a craftsman according to the usages of the trades, to open even the smallest place of business within the city, nor even to use a workshop for the carrying on of his favorite experiments.

At this juncture his connection with the university stood him in good stead. The senate having complete control of all that went on within the university precincts, granted Watt the use of rooms and a workshop in the college buildings, and appointed him "instrument maker to the university." Here he could ply his trade and carry on his business free from molestation by the city craftsmen. Nor did the professors grudge him any help that their science could afford. They made him their friend and confidant in their work, to the mutual advantage of their science and his practice.

He at first occupied himself especially in the making of navigational instruments, and he managed to earn a moderate living by the sale of these. Though he did not attend any classes in the university, he devoted himself very earnestly to the study of science. He thus gained the friendship of Dr. Black, who was lecturer on chemistry, and also held in succession the chairs of anatomy and the practice of medicine. Dr. Black thus speaks of him: "I soon had occasion to employ him to make some things which I needed for my experiments, and found him to be a young man possessing most uncommon talents for mechanical knowledge and practice, with an originality, readiness, and copiousness of invention which often surprised and delighted me in our frequent conversations together. I had also many opportunities to know that he was as remarkable for the goodness of his heart, and the candor and simplicity of his mind, as for the acuteness of his genius and understanding. I therefore contracted with him an intimate friendship, which was continued and increased ever since that time."

But Watt made another friendship in his college workshop, a friendship which had a great influence upon all his future life. A young student of natural philosophy—John Robison by name—was brought to the workshop by three of Watt's patrons—Dr. Simpson, professor of geometry; Dr. Dick, professor of natural philosophy; and Dr. Moor, professor of Greek, all men with strong leanings toward Watt's favorite pursuits. Robison, who afterward succeeded Dr. Black as lecturer on chemistry (in which science he got his first instruction from Watt), and who afterward occupied the chair of natural philosophy in Edinburgh University, gives remarkable testimony to the mechanic's knowledge of the exact sciences. "After first feasting my eyes with the view of the fine instruments, and prying into everything, I conversed with Mr. Watt. I saw a workman, and expected no more; but was surprised to find a philosopher, as young as myself, and always ready to instruct me. I had the vanity to think myself a pretty good proficient in my favorite study, and was rather mortified at finding Mr. Watt so much my superior."

Watt tells us that he owed to his friend Robison the first suggestion of "the idea of applying the power of the steam engine to the moving of wheel carriages and other purposes; but the scheme was not matured, and was soon abandoned on his going abroad."

The increase of his business and his approaching marriage led him to give up his rooms in the college, and in partnership with a man of some little means he opened a shop in the Saltmarket. Some three years later he removed to more commodious premises, as we learn from an advertisement in the Glasgow *Journal* of December 1, 1763, to the effect: "James Watt has removed his shop from the Saltmercat to Mr. Buchanan's land in the Trongate, where he sells all sorts of Mathematical and Musical Instruments, with variety of Toys and other goods." His connection with the university was, however, still maintained after he had gone into the toy business. He remained on terms of the most intimate professional intercourse with the science professors, and enjoyed their friendship in a more social way in the club which they frequented.

* An inaugural address delivered in the University of Glasgow, November, 1889.

His abilities and knowledge were so extraordinary, and so widely did they become known, that his contemporaries seemed to have considered him well nigh omnipotent in all matters pertaining to practical mechanics. When an organ was required for a masonic lodge in Glasgow, Watt was asked to build it, though it was well known that he had no ear for music, and could hardly tell one note from another. But in this matter we have revealed to us the secret of his success, and the chief lesson which his life must have for you who are entering upon the profession which he followed and so greatly adorned. He called science to his aid where his experience and his natural gifts failed him. He studied the principles which must guide him from "Smith's Harmonics," and by a thorough understanding of the "theory of the beats of imperfect consonance," he produced an organ which won the approval and even the high commendation of musical men. Nor did he make organs alone, but fiddles, flutes, and other musical instruments came from his hands.

Dr. Robison further tells us that "hardly any projects, such as canals, deepening the river, surveys, or the like, were undertaken in the neighborhood without consulting Mr. Watt, and he was even importuned to take charge of some considerable works of this kind, though they were such as he had not the smallest experience in."

After he had married and had begun to feel the necessities of a growing family pressing upon him, he forsook his orignal occupation of instrument making, and took to land surveying and civil engineering.

It is worthy of passing remark that both Watt, who may be looked upon as the founder of modern mechanical engineering, and Smeaton, who holds a corresponding place in regard to civil engineering, were mathematical instrument makers by trade.

Watt made a survey for a Forth and Clyde canal, and this involved his appearance before a committee of the House of Commons. I fear, however, that he would not have succeeded as a promoter of great national schemes in civil engineering work, as he seemed to lack some of the qualities necessary for success in the launching of such projects. Indeed, he had enough of parliamentary committees on this occasion, as appears from a letter to his wife written from London about this "confounded committee of Parliament." He writes: "I think I shall not long to have anything to do with the House of Commons again. I never saw so many wrong-headed people on all sides gathered together. As Mac says, I believe *the deevil* has possession of them!"

He persevered, however, with civil engineering works on a considerable scale, attained some celebrity in this branch of the profession, in river improvements, bridge, canal, and harbor works. Perhaps the greatest of his civil engineering works were his survey for the Crinan canal and a survey for a canal between Fort William and Inverness along almost the same line as that followed by the Caledonian canal, afterward constructed by Mr. Telford.

Here I must make a brief digression to explain Watt's place among the inventors of the steam engine.

The earliest workers in the investigation of the powers and applications of steam were, naturally and necessarily, learned and scientific men, according to their times, rather than mechanics. Such were Porta, Rivault, De Caus, the Marquis of Worcester, Huyghens, and Savery, who labored in the seventeenth century.

With the beginning of the eighteenth century the steam engine may be said to have passed from the hands of the philosophers to those of the mechanics. The essential details for an engine of a kind had been invented, and the scientific principles and data had been sufficiently discovered. The mechanical arts had so far progressed that the parts of the engine could be constructed, though indeed in a very rude manner. All that was wanted was a mechanic of ability and resource to take the matter in hand. Such discovered himself in Thomas Newcomen, the blacksmith of Dartmouth.

The miners of Cornwall had begun to encounter difficulties in their search for richer minerals at deeper depths than they had hitherto attempted to reach, owing to the frequent flood of the mines. Necessity produced her proverbial offspring. Newcomen constructed engines which were much in demand for mine pumping. In these engines steam at atmospheric pressure was admitted under a piston, which, by the descent of heavy pump rods, was caused to rise to the top of the cylinder. The communication with the boiler having been closed and the cylinder cooled by the application of water on the outside, the vacuum produced caused the piston to descend, raising the pump rods and water.

To prevent the access of air to the cylinder while the vacuum existed under the piston, Newcomen maintained a layer of water on the top of the piston. One day, while watching one of his engines at work, he was surprised to see it animated with unwonted vigor, and, searching for the cause, he found a hole in the piston which allowed the water to leak into the cylinder, accelerating the condensation, and producing a much better vacuum than he had previously attained. This at once suggested to Newcomen the expedient of injecting condensing water into the cylinder, instead of applying it to the outside. This and other improvements, including the self-acting gear which the valve-boy Potter contrived, to afford himself leisure from his duty of turning the cocks at each stroke of the engine, enabled Newcomen to produce much improved engines, whose only fault in the eyes of his clients was that they were too greedy in fuel.

A model of Newcomen's engine belonging to the university, and still preserved as one of the treasures of this place, was intrusted to Watt for repair in 1763. This circumstance could hardly fail to produce great results. Watt had all the necessary knowledge of science, he could work with his own hands, and further he possessed the instincts of a student and those of a scientific discoverer. Dr. Robison again says of him: "Everything became to him a subject of new and serious study, everything became science in his hands." Watt studied the model, experimented with it, discovered its wastefulness of steam, and set to work systematically to find the cause. He made numerous experiments, in the course of which he discovered the latent heat of steam, the theory of which had shortly before been worked out by his friend Dr. Black, unknown to Watt. He arrived at and clearly enunciated the principle which must underlie any attempt to greatly reduce the waste of fuel in the Newcomen engine. He saw that the chief source of loss lay in the cylinder being cooled at each stroke only to be reheated at the expense of the new charge of steam. He laid it down as an axiom, as he himself tells us, that "to make a perfect steam engine, it was necessary that the cylinder should be always as hot as the steam which entered it, and that the steam should be cooled down below 100 deg. in order to exert its full powers."

This led at once to his first great invention—from which all the others flowed—that of the separate condenser. The invention was fully worked out in his mind while he was taking an afternoon walk on Glasgow Green, and in a few days he had it put to the test of experiment.

Here then we have characteristic examples of two processes of invention. Newcomen, the blacksmith, made his success through accidental observation; Watt, the man of science, made his great invention by reasoning founded upon the knowledge of the laws of nature, which he had acquired through a long course of study and experiment. There was no accident here. His method was bound to lead him to the desired result.

Watt's other inventions are too numerous to mention, and most of them—such as the parallel motion, the governor, and the steam engine indicator—are well known to have come from him. But the very multitude of his inventions makes his name to be little associated with some of his most fruitful works. Had he made no other invention, or had he been of a more self-assertive disposition, his name would probably have become known, wherever business is conducted, in connection with his invention of the method, still almost universally in use, of copying letters by means of the copying press.

It would seem to be the common fate of all great and novel inventions to raise a storm of opposition from those whom they are most calculated to benefit. Dudley's invention of the process of smelting iron by means of coal, instead of charcoal, brought him only persecution from the iron masters, and the destruction of his works by rioters at their instigation. The steelmakers of Sheffield attempted to get the government to prohibit Huntsman from working his great invention—the cast steel process—and nearly succeeded in driving the cutlery trade out of their own hands, and out of Sheffield.

David Mushet's discovery that the "wild coals" were ironstones of great value, excited for years a strong prejudice against him in the minds of the iron masters of Scotland, who have since made not only their own fortunes, but in great measure the Scotland of to-day, through the working of those blackband ores. Neilson's invaluable invention of the hot blast for smelting furnaces was not only ridiculed by the iron masters, but so stoutly resisted that for years he was unable to get it even tried on a practical scale. So again the landed proprietors, who had perhaps most to gain from the opening up of communications through the country, strongly opposed the early railway projects. They supposed that they were to be reduced to beggary by the "infernal railroads," as one landowner called them, declaring that he "would rather meet a highwayman, or see a burglar on his premises, than an engineer!" Many more such instances might be quoted.

We need not, therefore, be surprised to find that Watt's copying process, though brought out practically in its present state of perfection, found little favor at first with many business men; but it is curious now, after the invention has for more than one hundred years been almost indispensable to the class of men who then resented its introduction, to read of the bitterness of the opposition which it met with. The fear that "it would lead to the increase of forgery" ran so high that on one occasion when Smeaton and Boulton (Watt's partner) were sitting in a London coffee house, they heard a gentleman exclaiming against the copying machine, and "wishing the inventor was hanged and the machines all burnt." No one could attempt to estimate the value to the world of this single invention, and still comparatively few people now know to whose labors and knowledge they owe the boon.

As an example of his more purely scientific work, I need only refer in passing to the part he took in the discovery of the composition of water, which gave rise to a long and somewhat bitter controversy.

I have referred to the patronage and protection which the university extended to Watt at the most critical period of his life, and the aid which he received from the science which he learned within its walls. The senate of those days earned for their ancient university the immortal credit of having started James Watt upon that series of inventions which have so altered all the conditions of life and labor.

The happy results which have flowed from this early patronage of the mechanical arts, and the application to them of the science of our predecessors, here need not be dwelt upon, and cannot be enumerated. Everywhere they are apparent, and every day they are being added to and extended. Old arts are giving place to new, and "the Scottish brass smith's idea," to quote the words of Carlyle, "is rapidly enough overturning the whole old system of society." To the labors of Watt, and therefore, in a considerable measure, to our predecessors on the senate of this university, we owe the first necessary steps in the modern scientific development of the arts both of peace and of war.

In later times again, the senate of this university, by its liberal encouragement of applied science in the labors of another great master of the art of invention—labors carried out, I believe, in the very rooms in which Watt worked and studied—has been largely instrumental in bringing about another of the greatest and most beneficent changes in the conditions of the lives of men. If through the labors of Watt the Atlantic Ocean may be said to have been narrowed from a month of discomfort and danger to a week of ease, so, largely through the labors of Sir William Thomson, the separating sea may almost be said to have ceased to exist as a barrier between the thoughts and lives of men of our race. These are among the greatest and most beneficent of the applications of science to the wants of man.

In past ages, when the universe was supposed to be divided against itself, when one system of laws was believed to govern the higher manifestations of the creative power, and quite another and baser set of principles to underlie all that concerned man's immediate material surroundings, we cannot wonder that the pursuit of the arts of construction and production were deemed beneath the notice of the noblest and most gifted men. Then the mechanical arts stood apart, and deserved and required no place in the universities, because they had little or no connection with other departments of thought and action. For it is the function of a university to teach, not what is limited and isolated in human knowledge, but to teach each separate department of knowledge in its relations to all others.* Now, however, when we see in all nature the manifestations of one and the same code of never changing, never varying laws, surely we may look upon the work of the engineer in "directing the great sources of power in nature for the use and convenience of man" as a vocation as noble, and as worthy of the highest order of mind, as that of the scientific discoverer, who deciphers, from their manifestations in nature, the principles which the engineer applies. And, surely, when a new application of the laws of nature is invented, which will open fresh possibilities in the lives and actions of man, he by whose genius and knowledge it is created may with as much joy and pride cry out "Eureka! Eureka!" as may he who first discovers a new and far-reaching principle of the universe, and sheds fresh light upon a dark page of the book of nature.

In the present state of man's progress, when the aid which science can give to the arts has not been fully accepted and made use of, devotion to the creative arts may not demand for success the exercise of a mind so richly endowed and cultured as is necessary for the inquiry into the secrets of nature; still in itself it may even appear to be of a higher form of exercise of the powers with which man has been endowed. Bacon indeed asserts: "The introduction of new inventions seemeth to be the very chief of all human actions. . . . Inventions make all men happy, without either injury or damage to any one single person. Furthermore, new inventions are, as it were, new erections and imitations of God's own works."

And if it is unnecessary, as I have said, at least in this university, to plead the cause of education in the sciences applicable to the work of the engineer, it is equally unnecessary to dwell upon its value in addressing present or future members of the engineering profession. If proof is wanted of the value set by engineers themselves upon such a course of study as that which enabled Watt to strike out into new and untrodden paths in invention and discovery, surely it is to be found in the liberal support now being given in all parts of the country toward the founding and equipment of schools of engineering science.

Almost every university, university college, and technical school now offers instruction in the science of engineering, and the support extended to these schools has not stopped with the founding of chairs and lectureships. Laboratories have been erected and equipped in which experimental investigations may be made on matters relating to engineering principles and practice.

There is, I fear, a rather common impression that an engineering laboratory is merely a workshop, in which students are instructed, or supposed to be instructed, in handicraft work. It is not so in most cases, and it ought not to be so. There are perhaps three principal subjects in engineering science which lend themselves especially to, and, indeed, demand, experimental treatment, and those are the three subjects in relation to which my three predecessors in this chair are so widely known and highly honored in the engineering world. Professor Gordon is principally known in connection with his work on the strength of structures, Professor Rankine's fame largely rests upon his invaluable contributions to the science of thermodynamics and its application to the theory of the steam engine, and my immediate predecessor, Dr. James Thomson, will ever have an honored name where the science of hydraulics is studied or applied. An engineering laboratory should be fitted up with the appliances necessary for the carrying out of experimental investigations in at least those three subjects or groups of subjects.

Testing machines should be provided by aid of which experiments may be made on the strength and elasticity of the materials used in civil and mechanical engineering construction, and on the strength and stiffness of elementary structural parts, such as columns, struts, and beams.

A specially designed steam boiler and engine should be provided, so that the students may be instructed in the experimental methods of investigating the economy of steam engines and boilers. No doubt the results obtained from such an engine as can be provided and used in a college laboratory cannot be an absolute guide as to the results that will be obtained from engines under all the conditions of ordinary practice, still the methods of accurate engine testing in the use of indicators, friction brake dynamometers, and other appliances, and in the quantitative determination of the various losses of energy, can be taught and practiced, and it must be remembered that such education in methods and principles, and not the imparting of separate facts and data to be remembered, is the main object of a university course.

The laboratory equipment should further include a set of tanks and other hydraulic apparatus to enable the students to carry out for themselves such experiments in the gauging of water, the efficiency of hydraulic motors, and kindred subjects as those which Dr. Thomson has carried out with so much ability, and such lasting benefit to engineering practice. Many minor subjects may also be experimentally treated in the laboratory with great advantage, such as the friction of lubricated and non-lubricated surfaces, and the efficiency of different methods of transmitting power.

Such matters cannot be learned in the ordinary course of pupilage or apprenticeship. The functions of engineering laboratories are thus referred to by Professor Kennedy, F.R.S., who must, in large measure, be regarded as the founder of the system now almost everywhere adopted: "In an ordinary pupilage a young engineer does not have much opportunity of studying such things as the physical properties of the iron and steel which he has to deal with, nor the strength of those materials, nor the efficiency of the machines he uses, nor the relative economy of the different types of engines, nor the evaporative power of boilers. These things, however, are only types of many others about which it is essential, not only that he

* See "The Unity of the Sciences," by Principal Caird.

should know something, but that he should form some definite working opinion. They are, to a wonderful extent, suited to set the student free from the thraldom of the engineering pocketbook (making "every man his own Molesworth," as it has been put), by helping him determine for himself or, at least, to see practically how other people have determined, all the principal engineering constants, from the tenacity of wrought iron to the calorific value of coal, or the discharge coefficient of an orifice. Further, a healthy skepticism of uncritical generalizations, or of uninvestigated facts, is fostered by nothing so surely as by a personal and practical knowledge of what accurate experiments really are."*

And not only do such laboratories supply a connecting link in the engineer's training between his work in the lecture room and his dealings with actual matter and energy in the practice of his profession or trade, but they enable the college work to be maintained in close connection with the engineering practice of the district, by supplying a want often felt, and largely taken advantage of where supplied, of an institution in which may be carried out tests for materials and other experimental investigations required by local engineers in the course of their business.

Such laboratories are now too numerous to mention in detail, but I may refer in passing to those of University College, King's College, and the Central Institution in London; those at Oxford University, at Cooper's Hill, at Bristol, and at Birmingham; at Edinburgh University, at University College, Dundee, at the Heriot-Watt College, Edinburgh, and at the Glasgow and the West of Scotland Technical College. The Victoria University has admirable laboratories in each of its three colleges at Manchester, Liverpool, and Leeds. There is the splendid Whitworth Engineering Laboratory at Owens College, Manchester, and the laboratory which I had the honor and privilege to design and conduct at the Yorkshire College, which was erected and equipped at a cost of 10,000*l.*, entirely subscribed by the engineers of Leeds. But all these that I have named have now, in some respects, been put into the shade by the magnificent Walker Engineering Laboratories opened recently at University College, Liverpool, which have been provided at a cost of 20,000*l.*, through the munificence of Sir Andrew Walker, a Scotchman resident in that city. Need I say in echo of the words of a letter from Sir William Thomson regretting his inability to be present at the inaugural ceremony of these laboratories, that "I am most envious of them for Glasgow."

Glasgow is second perhaps only to London as a center of civil engineering practice, and has further been called, not inaptly, the metropolis of mechanical engineering. Should not the example, then, that has been set by every other town in which engineering science is taught be followed here? And what could be more fitting than that an engineering laboratory, worthy alike of this city and the traditions of the chair which I have the honor to occupy, should be erected in this university, to which the engineering world, and through it the world at large, owes so much as a memorial of the genius and a tribute to the services of James Watt? Such could not be more fittingly dedicated than in the eloquent words of Lord Brougham inscribed upon the Watt monument erected in Westminster Abbey by the king and Parliament: "Not to perpetuate a name which must endure while the peaceful arts flourish, but to show that mankind have learned to honor those who best deserve their gratitude."

And now a single word to those who are entering upon the study of science with a view to its application in engineering work, and who naturally look with anxiety to the future. Let Watt's life afford you an example, and his success an encouragement. Get all the science you can, and blend it with a thorough practical experience, and you will find in your own careers a verification of the old Persian proverb, "A stone that is fit for the wall will not be left in the road."

*See Kennedy on "Engineering Laboratories," Minutes of Proceedings of the Institution of Civil Engineers, vol. lxxxviii.

THE SOULEUVRE VIADUCT.

THE line from Vire to Saint Lo and Caen, of which the first section was opened for exploitation in 1886, and of which the rest is in the course of construction, traverses the busy region of the Norman "grove," where the irregularity of the accidents of the land and the unequal hardness of the rocks complicate the problem of the direction line of railways and render it particularly interesting. After profound studies, in the course of which numerous variants were eliminated, the administration, in accord with the commissions of inquiry, of the Channel and of Calvados, selected the solution that was esteemed by it the most favorable to traffic and, at the same time, the least costly, although including a viaduct of exceptional dimensions over the Souleuvre.

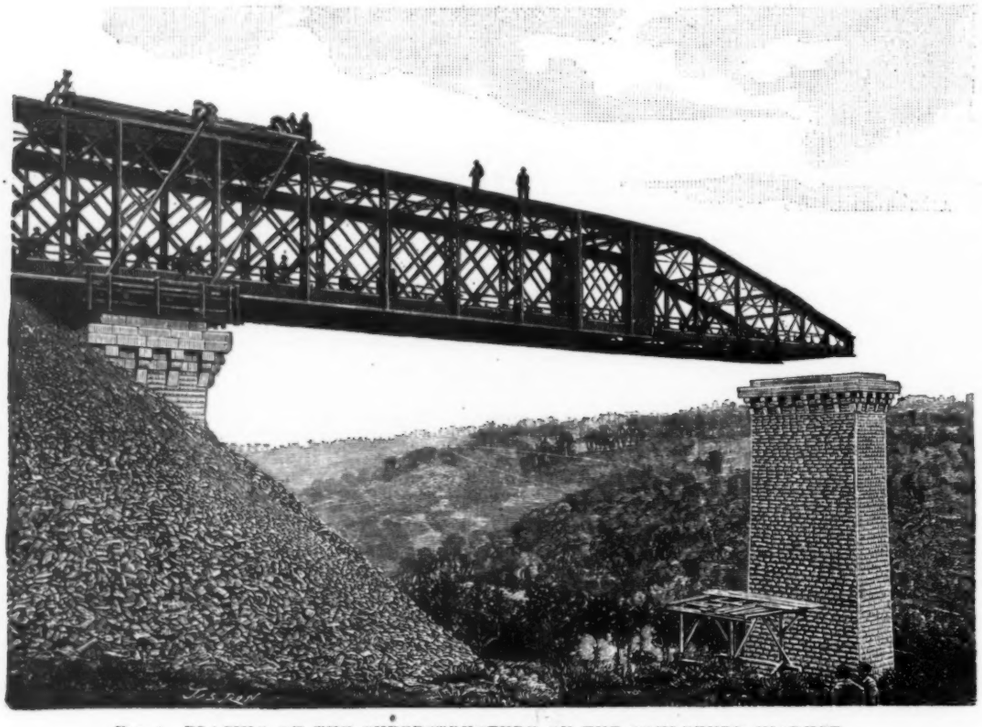


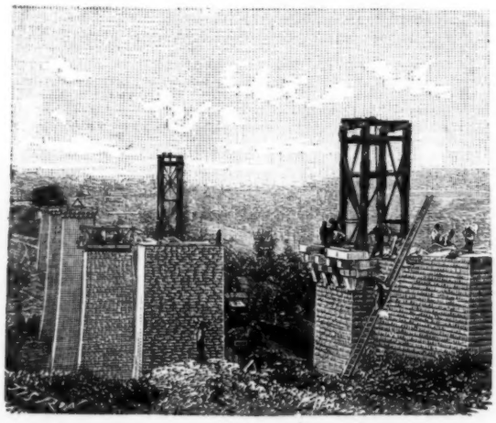
FIG. 1.—PLACING OF THE SUPERSTRUCTURE OF THE SOULEUVRE VIADUCT.

The Souleuvre, an affluent of the Vire, flows through a deep valley, whose section, where the line passes, approaches a trapezium of which the lower and upper bases are respectively 263 and 1,312 feet, and the height 230 feet. The plateaux which end there have, on each side, a pronounced slope toward the valley. Under such circumstances, the choice lay between a viaduct entirely of masonry and a work with metallic flooring and continuous straight girders. The Railway Company of the West, which had to draw up the project, discarded the first solution, through motives of economy, and decided upon a metallic superstructure of six spans resting upon masonry piers.

The viaduct has a total length of 1,200 feet. The total stretch of 1,142 feet between the axes of the supports upon the abutments is divided into two extreme spans of 165 feet and four central spans of 203 feet from axis to axis of the piers.

The track is installed at the lower part of the superstructure, the implantation of which, determined by the condition of a minimum of expense, places the rail at 206 feet above the bottom of the valley.

The two principal piers (Nos. 3 and 4, starting from Vire) reach a height of 198½ and 203 feet above ground. These are the highest of similar constructions in



FIGS. 2 AND 3.—PIERS IN COURSE OF CONSTRUCTION.

masonry. Among the metallic piers hitherto constructed, those of the Kinzua viaduct in America alone surpass them in notable height.

By placing the track at the top of the superstructure, it would have been possible to reduce the height of the piers by a certain number of feet; but it would have been necessary to increase, by just so much, the depth of the trenches opened in the compact rock, in order to establish the platform for mounting the superstructure and the tracks giving access to the same.

is under a load and there is no wind, may be raised to 1,585 lb. under a wind of 65 lb. to the square foot.

The profile of the piers has been studied in such a way as to reduce their cubage to a minimum, without exceeding the above limits and without exposing the masonry to any tractive stress. Such a condition has been fulfilled with more than a sufficient approximation by adopting for the templet of each a parabola of the second degree with horizontal axis. The broken line substituted for this curve on execution

which from the plane of the angles varies from 2¼ to 4 inches, and the height of the courses of which decreases from 10 to 5 inches from the base to the summit of the large piers, are of calcareous marble derived from the quarries of Montmartin-sur-Mer, near Coutances. The dressed stone, which appears only in the crowns, is granite from the region of the Vire. The mortar is made of Teil lime. As there is no sand in the region, it is procured by pulverizing the quartzose pudding stones that are met with in the vicinity, at the Mont

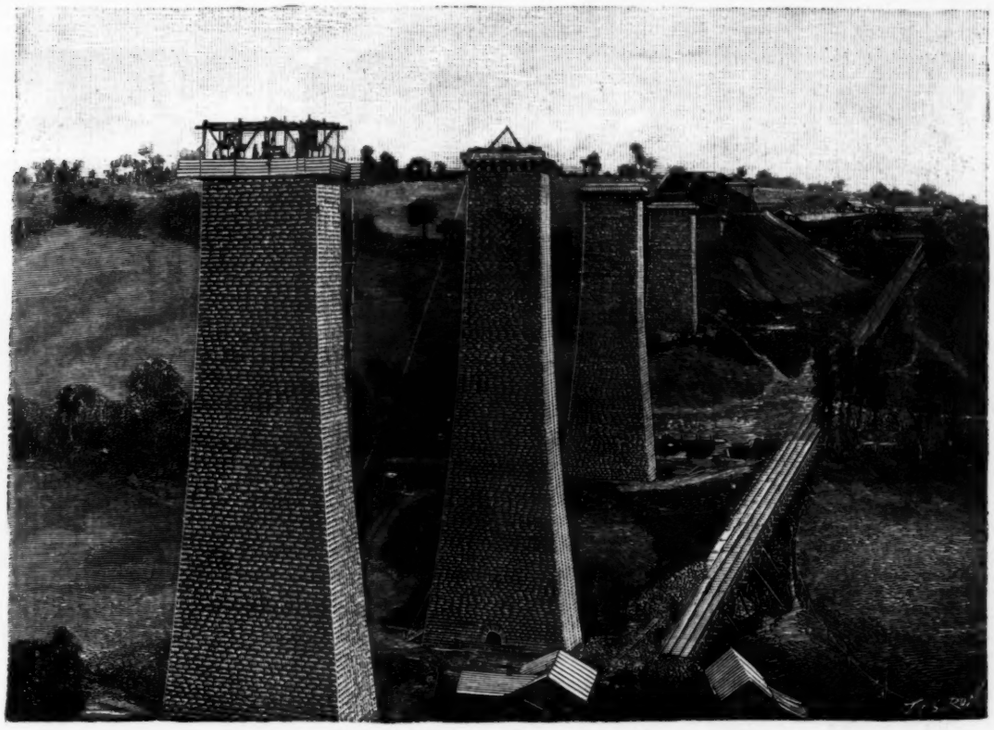


FIG. 4.—MASONRY PIERS OF THE SOULEUVRE VIADUCT.

The result would have been a great increase of expense, instead of economy. It is superfluous to add that the superstructure with track beneath offers more resistance to the wind and more security in case of derailment.

The horizontal section of the piers is rectangular. They are provided at the top with a widely projecting crown, in which is reserved a suitable space around the apparatus of dilatation upon which the superstructure immediately rests. The height of this crown, including the sharply cut consoles, which individually emerge from the facing of the rubble work, is 8¾ feet. Beneath the consoles, that is to say, in its smallest section, the pier is externally 20 × 13 feet. At the base of the largest pier these dimensions are more than doubled. The splay of the shaft, from the summit to the base, is realized by a series of increasing batters, each 16 feet in length, and the discontinuity of which is not appreciable to the eye. No offset, no horizontal line, thus breaks the elevation of the pier from the ground up to upper table of the crown. As all the horizontal sections of the body of the pier, moreover, are alike, the four corners, which are the only lines ap-

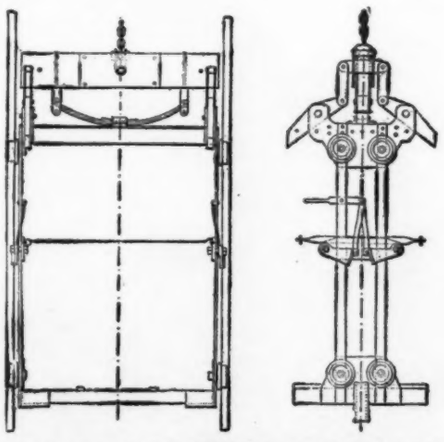
has, consequently, its successive batters in arithmetical progression, thus simplifying the calculations of resistance and implantation. The initial batter, under the crown, is 0·00625 for the faces transverse to the track, and 0·0137 for the lateral faces. Despite the lowness of the first of these figures, there is no illusion of overhanging, probably because of the contrast of this batter, of an extent of more than 12 feet, with the absolute vertical of the abacuses of the crown, which have been intentionally made very thick.

All the piers and abutments are founded directly upon very hard schistose strata, inclined about 45°, and sometimes presenting faults filled with clay, beyond which it was necessary to extend the excavating—especially at pier No. 4, which has the deepest foundation and is at the same time the highest. Underground, the facing masonry continues in a line with the elevation profile to a depth of 3 feet, in order to protect the rough masonry against frost, which the materials used could not resist. At this level, the pressure is reduced by a first offset, followed by a very marked batter (one-third), and by a second offset on a level with the top of the rock. The pressure of the foundation

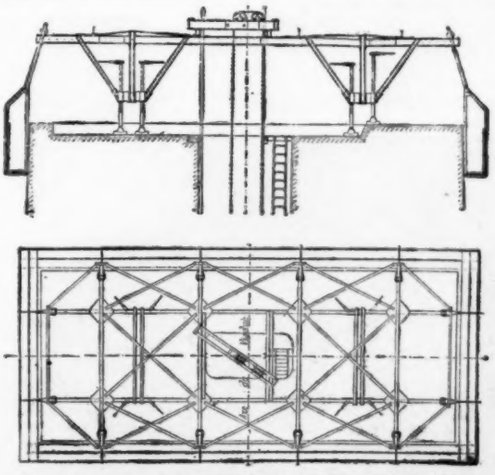
Beny quarry; the same quarry furnishes the rubble stone, and also the ballast for the section comprised between Vire and the viaduct.

The supplying of the materials presented great difficulties. In order to avoid ruinous carriages by roadway, the Company of the West began by laying and equipping a track for the 9 mile section between Vire and the viaduct. The facing stones, the dressed stone, and the lime are carried on this track to the edge of the valley without transfer of the freight. The line is connected with the quarry that furnishes the rubble, ballast, and sandstone by means of a track of 3¼ foot gauge and 4,600 feet in length, exploited with locomotives, and prolonged into the quarry by a large automatic inclined plane.

It is at the moment of forced transshipment (on the principal line) of the rubble and ballast that the debris of these materials are converted into sand by means of a Loizeau crusher, completed by a screen that separates the argillaceous gangue from the pudding stone, under the form of a fine dust. A second automatic inclined plane lets all the materials down to the bottom of the valley. Those of pier No. 5 and of the Saint Lo abut-



FIGS. 5 AND 6.—LONGITUDINAL AND TRANSVERSE ELEVATION OF THE ELEVATOR CAGE.



FIGS. 7 AND 8.—LONGITUDINAL ELEVATION AND UPPER PLAN OF THE ELEVATOR FRAME.

parent of this part of the structure, are plane lines that one can straighten by placing the eye in one of the two diagonal planes.

By reason of their exceptional height, the resistance of these piers has been calculated in taking into account the stresses that the wind may exert upon them, as well as upon the superstructure and the trains that run thereon. The maximum pressure, which is only 1,056 lb. to the square inch, when the superstructure

upon the earth scarcely exceeds 660 lb. to the square inch.

The cubage of the largest pier is 197,680 feet, foundation included, and that of the masonry in general about 706,000 feet.

The body of the piers is constructed entirely of rough masonry, and the facings of bossage, the four angles alone of the pier being relieved by a chiseling 4 inches in width on each face. The stones, the projection of

ment are raised upon the opposite side by means of a Decauville railway of 20 inch gauge, with horse traction. The base of each pier is connected either by inclined planes or by Decauville tracks.

The object of the most interesting part of the installations is the elevation of materials in the high portions of the large piers. Up to a height of about a hundred feet above ground the stone is raised by an ordinary steam elevator in a Lacroix tower made of joists. For

the masonry executed above this level, if it is expedient, the raising is done within the pier by means of an apparatus like those used in mine shafts, and comprising, essentially, a guided cage (Figs. 5 and 6), with a chain wound below around the drum of a steam windlass, and running above over a pulley supported by a frame. The guides of the cage consist, on each side, of a pair of wheels hugging an upright formed of U irons placed end to end in measure as the pier advances, and bolted to wooden sills set into the masonry.

The trolley containing the rubble of all kinds, or the mortar, is introduced into the cage from the track that ends there. Reaching the summit, it is rolled out of the cage on to planks, and remains to be unloaded while the cage takes down the trolley that has preceded it. The large dressed stones for the crown are the only ones raised without the trolley, and for the corner stones, which are the heaviest, the car is dispensed with and the chain is doubled by way of precaution.

The elevator serves also to carry the workmen up and down at the beginning and end of their work; and especial arrangements have been made for safety. A shield of thick boiler plate above the cage protects its contents against the rubble that might fall from overhead, and this, too, independently of the plank cover that normally closes the orifice of the shaft and increases the working surface. In case of breakage of the chain, the cage is stopped in its descent by automatic brakes each formed of a pair of sharp metallic dogs which catch into the sides of the shaft. These dogs are connected with a system of levers interposed between the chain and the cage, and are forced out normally only through the tension of the chain. Besides these automatic brakes, which are two in number and independent of each other, the cage is provided with two hand brakes consisting of a lever by means of which a pair of eccentrics or jaws may grasp and squeeze one of the guides.

Another and quite frequent cause of accidents in such apparatus is the shock of the cage on reaching its destination, either at the top against the pulley or at the bottom against the ground. In the descending apparatus of mines and of hoists with a fixed travel, the stopping points are signaled to the engineman by a device fixed to the chain. In the case under consideration, the length of travel increases in measure as the pier rises, and the same means cannot be employed unless the signaling devices are changed several times a week. On the Souloure viaduct it is combined with the use of an electric bell for controlling the starting, and, if need be, the stoppage, from the top of the pier. The materials are ordered by optical signals. The well left in the axis of the pier has a rectangular section of 4×8 feet, and its angles are rounded. This section comprises, in addition to the place of the cage, a small stairway formed of a series of wooden ladders with flat steps, each 6½ feet in length, assuring the passage of the workmen without interruption of the service of materials, and, if need be, the saving of life in case of accident to the mechanism. The framework of the elevator (Figs. 7 and 8) is a light iron frame assembled by bolts. It may be taken apart in portable sections. It rests upon the pier through four feet, each formed of a pair of screw jacks of three feet travel, and is gradually raised in measure as the masonry advances. To this effect, when the four supports begin to interfere with the work of the masons, one of the jacks of each pair is screwed up to its full height and is keyed by means of machines placed upon the last course of masonry and forming a bridge upon the reserved parts; then the four raised jacks are so maneuvered as to cause the frame to rise, and this carries along the other jacks. These latter being disengaged, work can be done beneath, and the interrupted courses be completed.

The framework can be covered so as to protect the masons against rain. It supports, besides, a service bridge provided with a plank inclosure, and permitting of moving in safety all around the pier at two or three courses below the level of the top. This arrangement presents serious advantages: it facilitates the execution of the masonry of the facing, increases the number of men capable of working on the pier, gives complete security, and permits of an efficacious surveillance of all the details. A very simple arrangement holds the bridge against the four faces of the pier in measure as the section diminishes in rising.

The system as a whole operates in the most satisfactory manner. It assures of a supply of materials more than sufficient for the use of all the masons who can work upon the pier. The security leaves nothing to be desired, for the last pier is nearly finished without any accident having happened. The chain, however, has several times broken, but the atmospheric brakes have sufficed to arrest the ascent of the cage almost instantly. One of the advantages of the system is that of escaping the action of the wind, against which it is difficult to protect a tower of more than 180 feet without making a genuine monument of it.

It is to be noted that the well has been employed even in piers whose height gave no occasion for the use of a special apparatus. It has been used for carrying up the mortar by hand windlasses, and has thus permitted of increasing the power of external hoists to supply material.

The rejointing of the facing is performed without difficulty, despite the height, after the completion of each pier, by means of a suspended platform upon which two masons take their place. The suspension cables, fixed by cramp irons to the stones of the crown, are maneuvered by means of pulleys, by the masons themselves, who supply themselves with mortar by the same process.—*Le Genie Civil.*

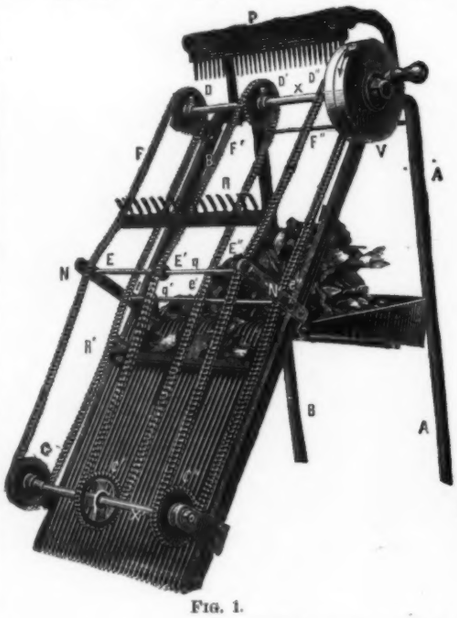


Fig. 1.

Fig. 2.

MACHINE FOR CLEANING GRATINGS.

MACHINE FOR CLEANING GRATINGS.

At the Paris exposition there was shown a small and very simple apparatus designed for cheaply cleaning the gratings of turbines and other hydraulic apparatus of the kind installed upon streams that carry along plants and detritus of all sorts.

As this apparatus appears to us to be destined to render great services in practice, we have thought that it would be of interest to give a brief description of it from data furnished by the Messrs. Delubac, its manufacturers.

As a whole, it consists essentially of two similar frames, A and B, arranged on each side of the grating to be cleaned, and fixed to it by means of bolts and cross pieces. Two bearings, O and O', at the top of the frames carry a driving shaft, X, upon which are keyed the pulleys that receive motion from the motor, and the toothed wheels, D, D', and D'', over which pass the endless chains, F, F', and F''. Two supports, N and N', fixed to the middle of the frame, are connected with each other by fixed axes, Q and Q', upon which revolve small toothed wheels, E, E', E'', and *e*, *e'*, *e''*.

The axis, Q, which may be moved in slides formed for the purpose in the supports, N and N', serves to stretch the chains when, through usage, they become slack and thus prevent the upper rake, R, from causing the descent of objects raised by the lower rake, such as leaves, sticks, etc.

The axis, Q', serves to prevent the chains from rubbing at the bottom against the bars of the grating and consequently wearing out. To the lower extremity of the frames are bolted two supports, M and M', which are connected with each other by a fixed axis, X', upon which turn three large loose cogwheels, C, C', and C'', arranged in correspondence with the wheels, D, D', and D''. The endless chains carry two or more rakes, R, R', of steel plate in a single piece, the teeth of which pass at the upper part between those of a comb, P, mounted upon pivots. This comb serves to clean the rakes on their passage.

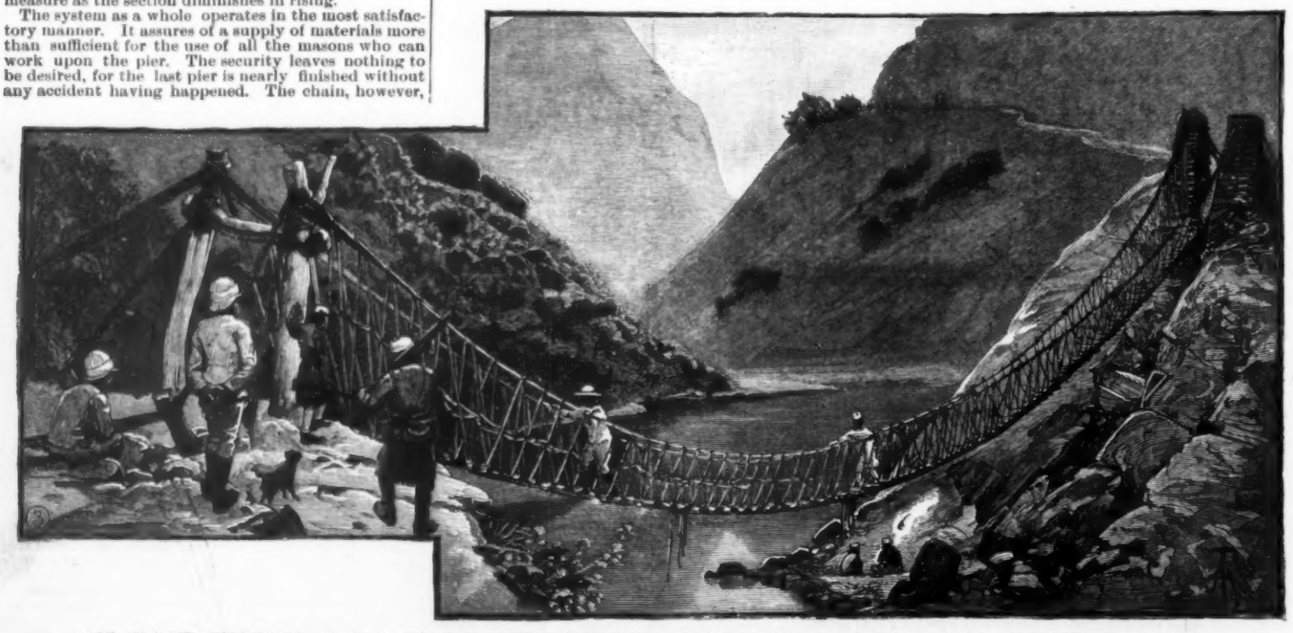
The apparatus, represented in front and profile in the accompanying figures, operates as follows:

When, under the action of a motor, the shaft, X, revolves in the direction shown by the arrow, the rake, R', scrapes the grating and carries along everything that is on it up to the platform above, upon which all the detritus is deposited. This rake is carried by endless chains upon the bottom of the grating and passes over while the other rake, which has followed the motion, has cleaned the grating in its turn.

We believe it useless to dwell further upon this apparatus, the principal advantages of which may be summed up as follows:

1. It is destined to extend the adoption of the turbine as a hydrauile motor by rendering its operation irreproachable. Hence, the greater facility for using all waterfalls as a motive power.

2. It does away, night and day, with manual labor in



AN EAST INDIAN "JHULA," OR ROPE BRIDGE—MADE OF BAMBOO AND TWISTED GRASS.

the cleaning of the grating, and, consequently, the corresponding expense, irregularities, and many inconveniences.

3. It does its work surely, regularly, and as perfectly as possible, without stoppages.

4. It prevents cessations of work, especially at the epoch of the fall of leaves or in times of inundations while rivers are carrying along detritus.

5. By a continuous motion and its peculiar arrangements, it prevents frost from forming on the bars of the grate and frees it from ice.

6. The cost of installation, though variable, is always relatively small.—*Annales Industrielles.*

SOME EFFECTS OF HEAVY ELECTRIC CURRENTS.*

By G. M. HOPKINS.

IT is convenient to speak of an electric current as a fluid flowing through a conductor, but it is evident there is no transference of material particles from point to point in the circuit; and although it seems to be a settled fact that electricity, like light and heat, is a phenomenon of wave motion, the transmission of electrical energy along a conducter is still known as the flow of the current. Owing to the convenience of this term, it will probably continue in use, although in reality there may be no such thing as an electric current.

The character of an electric current is determined by two factors, viz., pressure or electromotive force, by virtue of which it is able to overcome resistance, and its volume or flow. The practical unit of pressure or electromotive force is the volt; the practical unit of the current is an ampere, and the unit of resistance is the ohm. When a current encounters resistance, it is diminished thereby. Thus it is that by Ohm's law the current is equal to the electromotive force divided by the resistance, which is expressed by the formula $\frac{E}{R} = C$. If the electromotive force is very high, while the volume is small, the current cannot be properly called a heavy current; if, on the other hand, its volume is large and its electromotive force small, the current is designated a heavy current.

Currents of this kind require a very large conductor to convey them. All of the connections of the circuits must be large and the contacts perfect. A poor or small contact in a conductor carrying such a current offers more or less resistance to the flow of the current, and is manifested by the production of heat at the point of resistance. I shall confine myself to this feature of the subject this evening.

Some interesting facts regarding the local effects of large currents may be demonstrated by means of two iron rods crossing each other at right angles, one rod being fixed, the other pivoted and provided with a long index. These rods are connected up in the circuit of the battery. When the current flows from the battery through these iron rods, the resistance of the contact of the rods causes a development of heat at the points of contact, and the consequent local expansion of the rods, as indicated by the movement of the index. Upon breaking the circuit, the metal cools as suddenly as it was heated, and the index immediately moves back to the point of starting. The distance through which the index moves is small, but noticeable, and when the minuteness of the portion of the metal actually expanded is considered, it is seen that the expansion is in reality very great. Different metals are not all affected in the same degree. As would be expected, the effect of heavy currents on good conductors, such as silver and copper, is less than it is on metals of inferior conductivity, such as iron and German silver.

The molecular changes effected in the metals are analogous to those produced in the lead of the Trevelyan rocker. In the Trevelyan rocker, however, the expansion takes place in only one of the pieces of metal in contact. I have designed a Trevelyan rocker of peculiar form, which will enable us to compare the action of applied heat and of heat generated locally by the passage of a current through a point of resistance. The clamps mounted upon the upright metal rods are arranged for holding plates of different metals. The rocking bar, which rests upon the edges of these plates, is of cylindrical form. In the side of the bar, at one end, is formed a narrow groove, leaving ridges which rest upon the edge of one of the metal plates. One of the plates is lead.

The brass rocking bar is provided with a light index to show the vibrations. When this bar is heated by means of a flame, and placed upon the edges of the metal plates, with the ridges in contact with the lead plate, it rocks violently, and if the index be removed, the rocker gives forth a musical note, which continues until the heat of the bar is reduced below the operative limit. This action is due to the local expansion of the lead by contact with the ridges of the heated bar and the subsequent rapid cooling of the lead on the separation of the surfaces. These operations occur with great rapidity, the two ridges alternating in the production of the effects.

If, after cooling the heated parts, a heavy electric current is passed through the standards, the plates, and the bar, the same vibratory motion is at once set up, and while, in the case of the Trevelyan rocker, lead seems to be the only metal available for one of the surfaces, in the electrical rocker the results are the same in kind, although different in degree, with all the metals and alloys tried thus far.

To render the movements clearly visible, a pendulum is applied. The ring at the upper end of the pendulum rod is provided with a set screw, which allows it to be shifted from one rocking bar to another. This arrangement also permits of placing the pendulum and bar in working position, without the necessity of leveling the base of the instrument. The current from one small cell of secondary battery or from two large bichromate cells connected in parallel circuit is sufficient to cause the pendulum to begin to oscillate from a state of rest, and to increase its amplitude of vibration until it describes an arc of several degrees. The heat generated by the current is conducted away so rapidly as to permit the apparatus to operate continuously.

By raising the pendulum so as to bring the convex side of the rocking bar into contact with the edges of the plates, and drawing the bar along lengthwise of the plates, first without the current and afterward with the current flowing through the apparatus, a great increase in friction is noticed as the current passes, the increased friction being due to the jutting out by expansion of points upon both the edges of the plates and the side of the rocking bar.

This effect is the same as that noticed during some of the earlier experiments with electricity as a motive power for railways, in which the rails were employed as conductors of the current. It was observed that the wheels which received the current from the rails had an enormously increased traction while the current passed. This was at first attributed to the direct action of the current, then to molecular change caused by the electrical heating of the surfaces in contact, but the phenomena has not been fully explained.

The contact between the wheel and the rail under the conditions of actual use upon railways is scarcely more than a short line. If the surfaces were perfect, as well as infinitely hard and rigid, the contact would be simply a mathematical line. In reality the surfaces in contact are so small that any current meeting the resistance of such a contact must produce some heat, which becomes greater as the current is increased. Experiments show that a current of several amperes, having a pressure of one volt or less, is required to secure good results.

The apparatus which I will now show you will illustrate this point. I have provided a shaft carrying a small cylinder of steel, and have attached to the shaft a fly wheel to secure an equable motion. Upon the steel cylinder I have laid a flat bar of steel which is connected with a spring balance. The circuit is arranged so as to take the current through the steel cylinder and bar. I will turn the wheel first while no current passes. I will then cause a current to pass through the cylinder and bar, and you will see by the deflection upon the scale that the friction has been enormously increased. When the circuit is broken, the deflection is again normal. In this experiment the conditions are the same as in the case of the electrical railway, the only difference being that the track is movable, while the wheel revolves upon a stationary axis.

Another remarkable effect produced by the passage of heavy currents through small contacts is shown in the process of electric welding, invented by Prof. Elihu Thomson, of the Thomson-Houston Electric Light Co., of Boston, Mass. The manner in which this invention has been carried out furnishes a notable example of a great modern industry based upon a single, simple, scientific discovery. While it had been long known that heat was developed in poor contacts, this knowledge could not be utilized practically so long as electrical science was, so to speak, in embryo. In the growth of this young science, possibilities have been developed of which we know only the beginning. Prof. Thomson has happily grasped and utilized one of these possibilities. His whole system of electric welding is based upon the resistance offered by small contacts to large currents. Broadly stated, the process of electric welding consists in pressing together the pieces to be joined, and then passing a very heavy electric current through the pieces. The resistance at the point or points of contact produces a welding heat, and the forcing together of the pieces makes a perfect weld. The heat increases the electrical resistance at the point of contact, thus, in some measure, facilitating the process.

The current requisite for this operation may be generated in several ways, but experience has shown that but two methods are available in practice; one is that of employing the inverted induction coil known as the transformer, and the system is called the indirect or transformer system. The other is the direct system, in which an alternating current of the required strength is produced directly by the dynamo.

The apparatus used in the first of these methods consists of an induction coil having a small primary wire wound upon the core, and a secondary conductor formed of a bundle of sixty-four No. 10 wires, wound around the primary and clamped to heavy bars of copper carrying the jaws in which the rods to be manipulated are held together. This particular apparatus is especially designed for joining small wires of copper, steel, and iron, band saws, etc. The heavy copper jaws which hold the wires to be welded are drawn together by a spiral spring.

When currents from an alternating machine pass through the primary wire of this inverted induction coil, heavy alternating currents of low electromotive force and great volume are generated in the secondary conductor, which in passing through the points of contact of the wires to be welded give rise to a welding heat.

In another type of transformer the secondary wire consists of a single heavy curved copper bar inclosing the secondary coil and terminating in arms provided with jaws for receiving the rods to be welded. The primary and secondary conductors are inclosed in massive coils of iron wire. The arms in which the secondary conductor terminates are drawn together by a powerful screw clamp furnished with a heavy spring for keeping a yielding pressure upon the arms, so that when the metal is heated and softened by the passage of the current, the spring will cause the jaws to approach each other as the softened metal yields. The resistance of the secondary bar in this apparatus is about one three-hundred-thousandth of an ohm.

Alternating currents pass through the primary cell, produce rapid reversals of the magnetic polarization of the iron surrounding the copper conductors, and there is a transfer of energy by induction to the circuit of the secondary bar. A current of 20 amperes and 600 volts in the primary may produce in the secondary a current of 12,000 amperes with a pressure of about 1 volt. The current in this case, as in the other, is supplied by an alternating current machine specially designed by Prof. Thomson for this apparatus. It is a remarkable fact that this alternating current machine has only 10 lb. of wire on its armature and 40 on the field magnets.

A compact and convenient device for welding small and medium work consists of a transformer and a pair of jaws, one of which is movable, the secondary of the transformer being made of a series of copper strips, forming a compound bar about 1½ inches square. The points of contact are forced together in this case by means of a screw operated by a pinion and spur wheel.

In the direct transformer the armature is wound with two coils, one of which is fine wire to supply the current for exciting the field magnet. The other is a single copper bar, which supplies the current for welding purposes. The ends of this bar are attached to insulated rings carried by the armature shaft, and the current is taken off from these rings by collectors attached directly to the jaws which hold the work. The electromotive force of the welding current in this machine is about one-half volt. One great advantage in this method of welding is that the power is absorbed only during the brief time required for welding; at other times the machine runs light, when the power consumed is practically nothing.

Prof. Thomson has kindly favored me with some particulars in regard to one of the recent machines turned out at the factory in Lynn, Mass. It is the largest yet produced. It is now in practical use welding heavy copper bars. In experimental tests of this machine at the Thomson-Houston works, the one inch copper bar and the one and one-half inch brass bar were welded. The current required to weld these bars is about the same in each case, that is, 30,000 amperes. To get a faint understanding of the amount of current required to produce these welds, I will state that it will require 90,000 cells of gravity battery such as is used in telegraphy to produce this current with an electromotive force of one volt, and double that number for an E. M. F. of two volts. This number of batteries would occupy an area of 25,000 square feet, they would weigh 250 tons. It will thus be seen that to accomplish this feat of welding by means of primary batteries is practically impossible. Welding has been done by the current from secondary batteries, but there are practical difficulties in the way of using the secondary batteries on a short circuit.

The smallest welds produced by Prof. Thomson were in platinum and German silver wire $\frac{1}{10}$ of an inch in diameter. Prof. Thomson thinks that the operation can be refined to such an extent as to be carried on under a microscope, but thinks it doubtful if on such a small scale it has any practical utility. The smallest currents at present used commercially range between 200 and 300 amperes. The largest iron bar that has been welded by the apparatus thus far is three inches in diameter. I am informed that machinery is in process of construction which will weld a 6 inch iron pipe. It is of some interest to know that the secondary of the immense transformer referred to had a sectional area of 56 square inches. It is a solid copper bar 8½ inches in diameter.

The difference between the inductorium, or ordinary induction coil used in generating currents of very high tension, and the inverted induction coil, like that already mentioned for producing large currents of low voltage, will be appreciated by a comparison something like the following: Mr. Spottiswoode's great coil delivers a spark in air having a length of 42½ inches and a pressure of about 250,000 volts. Prof. Thomson's largest transformer generates a secondary current requiring an immense metallic conductor to avoid heating. The electromotive force in this case, as already stated, is only one or two volts, whereas the current has the immense volume of 30,000 amperes. The secondary conductor of the Spottiswoode coil is 380 miles in length; that of the Thomson transformer is but three or four feet. The diameter of the secondary of Spottiswoode coil is one-hundredth of an inch; that of the Thomson transformer, 8½ inches. The sectional area of the secondary conductor of Spottiswoode is 75 millionths of a square inch; that of the secondary of the Thomson transformer is 56 square inches. In round numbers, the area of the large secondary would contain 750,000 of the smaller one. The resistance of the secondary of the Spottiswoode coil is 110,000 ohms, while that of the secondary of the Thomson transformer is immeasurably small.

NEW ELECTRICAL PROCESS FOR THE MANUFACTURE OF WHITE LEAD.

By TURNER D. BOTTONE, Hoosick, N. Y.

THE invention consists in electrically dissolving a lead electrode in an electrolyte containing nascent or free carbon dioxide, whereby the lead compound formed by electrolytic action is precipitated to form hydrated carbonate of lead or pure white lead, which is then removed, washed, and dried.

One method of carrying the invention into practical effect is as follows: The electrolytic solution can be prepared by dissolving one-half pound each of sodium nitrate and ammonium nitrate in one gallon of water, and then saturating the solution thus formed with carbon dioxide, which can be done in various ways. Sodium carbonate and ammonium carbonate may be used in the place of the nitrates; but in that case nitric acid must be added until the bath is about neutral, which results in the larger portion of the carbon dioxide being driven off during effervescence. The electrolytic solution is then placed in a suitable vessel or tank and electrodes of metallic lead are immersed in the same. The electrodes are then connected to a source of electricity, and for practical work I prefer a current density of about fifteen amperes per square foot of anode surface. Upon the passage of such a current between the electrodes through the bath the white lead begins to fall very rapidly. As the carbon dioxide is taken up from the bath to form the hydrated carbonate of lead, it is of course necessary to have the bath replenished with additional carbon dioxide as the process continues. This may be done in several ways. Porous pots filled with sodium or ammonium carbonate may be placed in the bath, and will there slowly dissolve out into the bath for the purpose of supplying the latter with the required carbon dioxide; but this method involves the ultimate over-saturation of the bath with sodium hydrate and free ammonia, which are of no use when once formed, and only tend to interfere with the most advantageous working of my process. I prefer to supply the carbon dioxide in some other way, and obviously the best method will be one which will supply it unaccompanied by any other material.

Where the electrolytic solution is made up of sodium and ammonium nitrates in water and the solution is saturated with carbon dioxide in its free state, the reactions taking place upon the passage of the electric current may be described as follows: The bath is decomposed, yielding at the anode nitrogen pentoxide, ozone, and oxygen, and at the cathode sodium hydrate,

* Abstract of a paper read by George M. Hopkins before the Department of Physics of the Brooklyn Institute, March 26, 1890.

ammonia, and hydrogen. The lead is attacked by the powerfully oxidizing nitrogen pentoxide (N_2O_5) and ozone; but nitrogen pentoxide in the presence of water is decomposed and forms nitric acid (HNO_3). During the double decomposition which takes place nitric acid (HNO_3) and plumbic acid or hydroxide of lead, $PbO(OH)_2$, are formed. The nitric acid combines with the free ammonia and sodium hydrate to again form sodium and ammonium nitrate, while the plumbic acid is precipitated by the free carbon dioxide present and forms finally the hydrated carbonate of lead, $2PbO\,CO_2+Pb(OH)_2$. Thus it is seen that although the solution is decomposed by electrolysis it is regenerated by the chemical reactions taking place, and the only loss sustained is carbon dioxide and water, which can be readily supplied. The white lead is from time to time removed from the tank, washed, and dried, and on mixing with a suitable vehicle into a paint is found to have much greater covering properties than ordinary commercial white lead formed by dissolving lead in acetic acid in the presence of carbonic acid, since the latter is slightly crystalline and less opaque than the hydrated carbonate produced by the action of carbonic acid on plumbic acid.

I have given what I consider the most practical and economical solution; but I wish to state that I do not confine the scope of my invention thereto, as various solutions may be employed without departing from my invention. For instance, I may use the nitrate or carbonate of any of the alkaline metals or earths; but I give preference to the combination hereinbefore named. Likewise the particular means adopted for the introduction of carbonic dioxide into the electrolytic bath may be varied from those given—such, for instance, as the action of diluted sulphuric acid on sodium carbonate or calcium carbonate, and in either of these cases the residue becomes a marketable product. The strength of the bath may be weak or strong without materially affecting the results; but I prefer the proportions given with regard to quantities, as also the amount of current per square foot of anode surface, and I also prefer that the bath should be kept at about 60° Fahrenheit.

DISEASES OF THE CRANBERRY.

WE are indebted to Professor Edward Merrill Gates, director, for bulletin sixty-four of the New Jersey Agricultural College. It contains an able article by Prof. Byron D. Halsted, upon the above subject. Among his conclusions he states:

The gall fungus of the cranberry, sometimes called "red rust," consists of a low form of plant that infests certain cells in the leaf, stem, flower or fruit, and causes abnormal outgrowths from the surface and finally ruins the crop.

It is probably at present confined to a single cranberry bog.

Several other shore plants belonging to the same family with the cranberry are also attacked, but only such of these as are bathed by water from the bog become infested.

One portion of the bog, long ago shut off by a railroad grade, has none of the gall fungus. One branch of the upper end of the bog, receiving all its water from a single stream, is also free from it.

The disease is carried in the water during the floods of spring, and is not readily transmitted through the air. It is likely that it could spread by means of birds and other animals, and by winds drifting the dead leaves of infested plants, like those of the huckleberry and azalea, over the snow crust in winter.

Withholding the water from the bog during the winter and spring may subdue the fungus, but it would probably be a quicker and even cheaper way to burn the infested plants, and this includes the shrubs along the borders and elsewhere that are attacked.

While the serious trouble is now so circumscribed it should be exterminated before getting into other localities, when it might be too late.

One of the most serious, as well as mysterious, troubles experienced by the cranberry grower is known in common language as "the scald." The loss from this disease in New Jersey is not far from one-third of the crop, and there is very little of this trouble outside of the State.

Upon the same bog the scald varies from year to year—a wet, warm season being most favorable to its development.

Various remedies, as lime, copperas, and other chemical compounds, have been employed by cranberry growers, but with no marked good effect.

Sanding the bog, and controlling the water so that it will be low in midsummer, have usually been a benefit to scald bogs.

The trouble is primarily due to a minute fungus that is found in all parts of the infested plant, and also in the surrounding soil.

What is best to be done with a bog that scalds is yet unknown, because no field experiments have been made. This work must be done upon the bog, and the station botanist will be pleased to outline trials and tests for those who are willing to share in the labor and expense of a systematic search for a remedy.

COMPOSITE PHOTOGRAPHY.

As well known, composite photography consists in the fusion of a certain number of individual portraits into a single one. This is effected by making the portraits pass in succession before the photographic apparatus, and giving each of them but a fraction of the normal exposure equal to such exposure expressed in seconds and divided by the number of portraits in hand. Theoretically, this is what occurs: The features peculiar to each of the portraits not having been sufficiently exposed (unless the number of them be too small), do not take, and the features common to all having been given a proper exposure, alone leave a visible trace upon the sensitized plate. Therefore, the result obtained may be considered as the type of a race or of a family, if the individuals that have served to obtain it belong to the same race or family. A very serious objection has been made to this theory, and one that would tend to do no less than show the absolute emptiness of its scientific value. This objection, however, which emanates from men of note from a photographic and scientific point of view, rests, fortunately, only upon a defective method of operating. What it consists in is this: According to a hypothesis enunciated a few years ago, but which now seems to be abandoned, the sensitized plate ought to be so much the more sensitive in proportion as it is oftener impinged upon by a very feeble light—too feeble even to leave a visible trace. It would result from this that the portraits under experiment would give an impression so much the more intense in proportion as their exposure took place more in advance of the general exposure; in other words, the last portrait exposed would have a preponderant influence over the final result, so that the latter might vary at the pleasure of the operator. Before so serious an objection, which my former experiments had never led me to suspect, I have instituted some new ones especially with a view of verifying the accuracy of them.

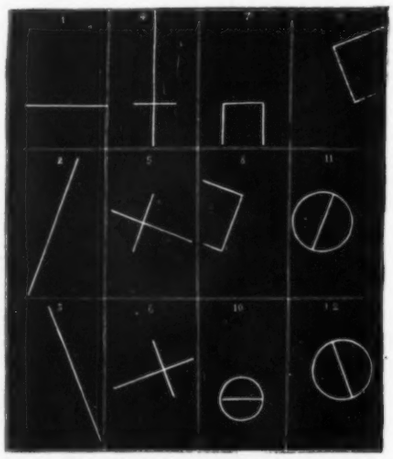


FIG. 1.—VARIOUS GEOMETRICAL FIGURES.

Upon twelve cards of the same dimensions (Fig. 1), I have drawn the same number of geometrical figures, which, grouped in threes, all form the same triangle, each forming but a portion of such triangle allied to another figure. If the objection mentioned above has any force, what shall I obtain by taking a composite photograph of these twelve figures? A triangle around and in the interior of which the individual lines of each card will exhibit an increasing intensity from No. 1 to No. 12 (Fig. 1)? Experiment proves that there is nothing of the kind. The triangle, which does not exist in any of these twelve figures, is well marked (Fig. 2), each of its sides having been taken four times; the other lines are scarcely indicated, and all are indicated to an equal degree. I was desirous of pursuing my experiments upon portraits, since, upon the whole, the final object of the method that I have occupied myself with is to operate upon these.

In Fig. 3, there are twelve portraits—six of men and six of women, belonging to the same population. I chose adults in order that the coincidence of the heads should be as perfect as possible. As may be readily seen, there are portraits of quite young persons and others of persons already aged. I made an exposure in succession of No. 1 to No. 12, that is to say, beginning with the youngest woman and ending with the oldest man; and then from No. 12 to No. 1, that is to say, in inverse order. I interposed a man and a woman, and renewed the experiment, preserving the same arrangement, but changing the order of the subjects. The result remained constantly the same, as may be readily seen by glancing at the four composites, A B C and D, of Fig. 3. I then made upon one side the type of six men (composite E), and, on the other, of six women (composite F). Here the change produced is very perceptible. It is always the same head, but while before we had a being of indeterminate sex, we find here with perfect distinctness a man on one side and a woman on the other. I wished to see whether twelve other persons (six men and six women again), taken from the same population, would give a type analogous to the first. As may be seen (composite G), there is a slight difference, but the character of the head is the same, the difference existing especially in the physiognomy. The same remark may be made as to the composite H obtained from the six women of the preceding group joined with the six women figured Nos. 1, 2, 3, 4, 5, 6, which alone gave the composite E. This observation proves (what was to be foreseen) that the more the number of subjects for each experiment is increased, the greater will be the probability of obtaining the true type of the population studied. On the contrary, when but three are taken (as I have seen done), a great risk will be run of generalizing too much. In this case, moreover, each exposure is necessarily too long, since it consists of a third of the normal exposure and is no longer the resultant of the three heads, but their superposition. Hence, the slightest increase in the length of one of the three exposures assumes considerable importance.

FIG. 2.—FAC-SIMILE OF A COMPOSITE PHOTOGRAPH OF THE GEOMETRIC FIGURES.

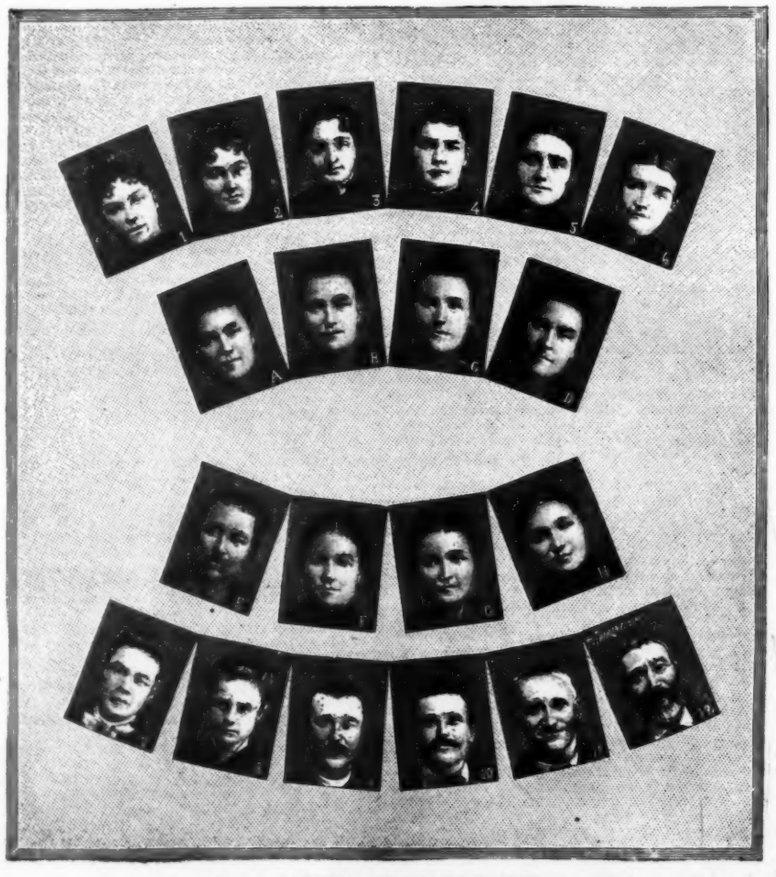


FIG. 3.—COMPOSITE PHOTOGRAPHS.

I insist particularly upon this latter point. It is strictly indispensable in such experiments to use a shutter that gives automatically the same time of exposure to all the portraits, and to make the time of exposure as short as possible. All my experiments demonstrate that the facts that have brought out the objection mentioned above have no other cause than the too small a number of subjects and unequal times of exposure.

I believe that composite photography is capable of extracting the type of a race from the individuals that compose it, and of thus rendering innumerable services to anthropology.

Relying now upon my new experiments, which prove what I advanced in 1887, I am happy to aver that it is indeed a strictly scientific process.—*A. Batut, in La Nature.*

THE SINGER SEWING MACHINE WORKS AT ELIZABETHPORT, N. J.

ON arriving at the dock of the Singer Sewing Machine Works, the party were met by the officers of the company and conducted through a fine park to the works, which were carefully inspected, and the various labor-saving devices thoroughly appreciated. In a manufactory where so many pieces are constructed and put together, even a slight saving in each aggregates to a large amount. A general description of the works is as follows: They are located on Newark Bay, and the main factory building has a frontage of 230 ft. on First street, with a width of 60 ft. The Trumbull street annex to this building is 800 ft. long and 50 ft. wide, the whole being four stories in height. Below this building, on Trumbull street, are the cabinet and box factories, each 200 ft. long and three stories high. On the north side of the grounds, adjoining the Central Railroad property, are the forging and foundry building, together making one continuous building 1,430 ft. in length. The foundry alone has an area of 2½ acres in one open floor, and the total floor area of the works is 18 acres. On the opposite side of First street is the Singer Park (private), which extends to Second street on the west, and occupies the space between Trumbull street and the Central Railroad of New Jersey, covering about 3 acres. The first Singer machine was made in Boston in 1851, and the firm of I. M. Singer & Co., the late Mr. Edward Clark being the "Co.," was formed during that year, the business being carried on in New York city. After various changes of location necessitated by an increasing business, the company came to Elizabethport, where they have both railroad and water facilities, being distant from New York city about 12 miles by rail and about 14 by water. The company have their own steamer, and consider they save considerably by its use; they also load their machines in cars at their sheds, and thus avoid cartage, and reduce breakage due to handling to a minimum.

The plot occupied by the works contains 32 acres, and has a dock frontage of 800 ft. There are over four miles of railroad track within the yard, on which two switching locomotives, owned by the company, are kept constantly employed. The works consume annually about 15,000 tons of coal, which is received direct from the mines, *via* Central Railroad of New Jersey, without rehandling. Gas for lighting and manufacturing purposes is made on the premises, and the company have their own fire department, thoroughly organized and equipped, including a system of electric fire alarm signals. They also have a complete telephone exchange connecting all departments with the main office and with each other.

On these premises the Singer Company have also extensive boiler works, entirely separate from the buildings already enumerated, in which they manufacture for the Babcock & Wilcox Company, of New Jersey, their patent water tube boilers, of which over 40,000 horse power were constructed during the year 1888. The steam power used in the works is supplied by twenty-two of these Babcock & Wilcox boilers.

The works give employment to an average of 3,300 individuals, and have a capacity of 1,500 sewing machines per day. They, of course, consume a very large amount of raw material, the daily melt of pig iron alone varying from 75 to 80 tons.

About $40,000 in wages is weekly distributed among the employes, the most of whom live in Elizabeth.

The present works were first occupied in the fall of 1873. Since that time various additions have been made, the last one being finished in the spring of 1888.

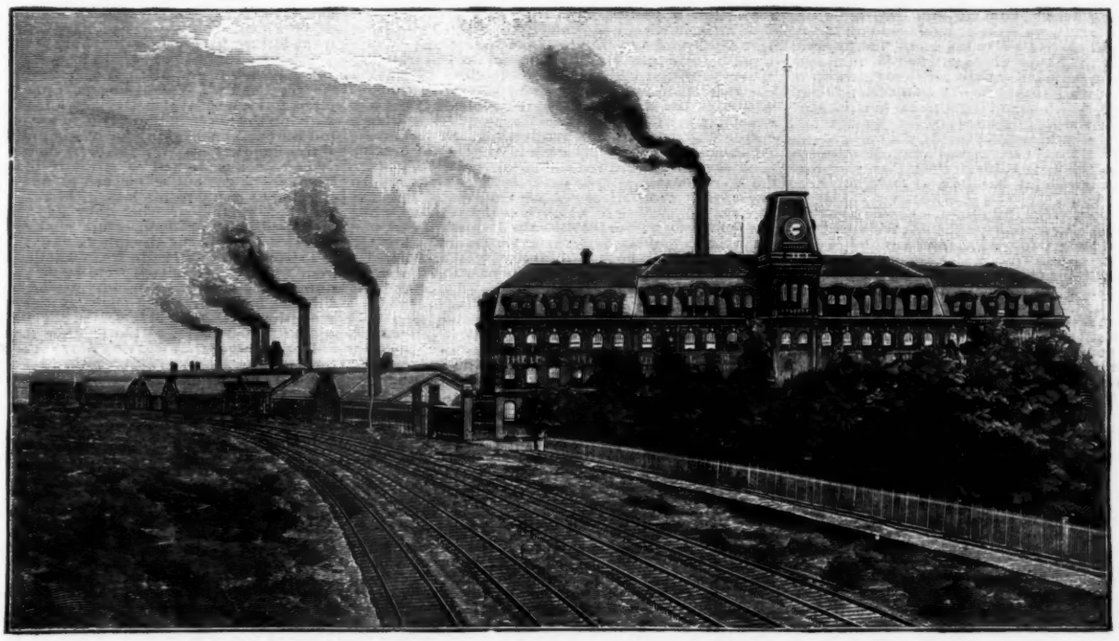
The Singer Company have thoroughly systematized the manufacture of sewing machines, introducing and successfully using automatic machinery in every department, and with their large corps of well trained employes, the work in their immense factory goes on with the precision and regularity of clockwork. In the factory everything is scrupulously neat, and every provision is made for the safety, health, and comfort of those who spend their time within its walls. Even the various rooms are heated by overhead pipes, and the ventilation problem has been carefully studied and solved with judgment. The emery wheels are protected, and the general air of the employes was that of industrious and skillful workmen who were satisfied with their position and appreciated the care their wants had received at the hands of their employers.

The visitor to the works will find that while a close and exhaustive study has been made of the strictly useful and practical, the beautiful has not been forgotten. Through the yard are scattered trees which overshadow well kept lawns, thickly dotted with flowers, and, indeed, the grounds, on which a force of men is kept continually employed, have more the appearance of a park than a factory yard.

The officers of the company are: F. G. Bourne, president; William F. Proctor, vice-president; C. A. Miller, secretary; E. H. Bennett, treasurer.

Some of the machiney proved to be of the greatest interest, especially that used in making the needles. The tasteful designs painted on the machines, such as bouquets of flowers and other decorations, are put on very much like the decalcomaine process, and this work is done by girls. The name of the company is put on in a similar way. The old method was to have these painted by hand. Some of the cabinets containing the machines attracted attention from the richness of the wood, and on inquiry we found they were made of cottonwood. They had a high polish and a beautiful grain. The question as to who used all these machines came constantly to the lips of the party, only to learn the company had a large series of works at Glasgow, Scotland, although they did not turn out as much as the Elizabethport ones.

After spending a delightful day and being very much impressed with the wisdom, skill, and forethought of the officers, the party re-embarked. The return to New York was charming, and the statue of Liberty seemed never to have looked so attractive.—*Engineering.*



FACTORY OF THE SINGER SEWING MACHINE COMPANY, NEWARK BAY.

[From the TRANSACTIONS of the Engineers' Society of Western Pennsylvania.]

THE REFINEMENTS OF MODERN MEASUREMENTS AND MANIPULATIONS.

By J. A. BRASHEAR.

PROGRESS is written to-day upon every page of the world's record; and particularly in the realms of science is it making its unmistakable mark; from thence extending outward to the vast range of correlated studies that go to make up the sum of human knowledge and economics. In astronomy and astronomical engineering, in physics and chemistry, in civil and mining engineering, in meteorology and in metrology and in mechanics, to say nothing of many other branches of science, do we find progress as the watchword and the theme that excites and moves the human brain to grander and better achievements. It is my pleasure, and an enjoyable privilege, to call the attention of this society, in my retiring address as your president, to some of these lines of progress in which I have for many years been interested, and which, I trust, will prove of interest to you. I shall therefore present some thoughts on the refinements of modern measurements.

When Dr. Alfred M. Mayer, of the Stevens Institute, published his splendid papers on the minute measurements of modern science in the SCIENTIFIC AMERICAN SUPPLEMENT, some fifteen years ago, it opened the eyes of many of our American mechanics to the possibilities of a refinement in measurements they had never dreamed of, and I believe those papers, written in such clear and untechnical language, have done an incalculable amount of good to mechanics, who to-day show it by their accurate work, to some of which I shall refer later on.

The day has forever past when we are willing to say or believe that "three barleycorns make one inch," nor is the advanced mechanic of to-day satisfied with his boxwood rule, graduated to thirty-seconds of an inch, save for the coarsest approximate measurements; but he must have his Brown & Sharp standard graduated to one one-hundredth inches for his *coarse* measures, and his micrometer gauges reading to one one-thousandth for his ordinary work. Even in our iron and steel works, the old-time wire gauge, that for a long time held its own, has been displaced by the modern micrometer gauge of infinitely greater accuracy.

My esteemed friend, Mr. George M. Bond, has said very appropriately that "the arm of King Henry the First, or the barleycorn, though possibly furnishing standards good enough for that time, would hardly satisfy the demands of our modern mechanics or tool makers, who work very often within the limit of one-thousandth of an inch, and even one-tenth of this apparently minute quantity, with surprising unconcern and no less accuracy." Prof. Wm. A. Rogers has also shown that many of our modern mechanics can caliper to one thirty-thousandth of an inch. These, however, are coarse, rough measures when compared with others I shall mention in this paper.

In the domain of astronomical measurements great progress has been made of late years by the use of refined instrumental means, as well as the many methods devised for the elimination of instrumental errors. The divisions of the meridian circle have been brought to astonishing accuracy. I may mention two of the best dividing engines in the world, which I have examined through the courtesy of the constructors. Perhaps the most celebrated is that of the Repsolds, in Hamburg. This wonderful engine has come through three generations of celebrated mechanicians, each one adding to its accuracy until now it seems to have reached the limit of human capability; in other words, as perfect as the environments of temperature, and other factors over which human hands and brains have no control, will allow it to be brought. The *maximum* error of the best circles divided by this engine equals 1·17". This engine is not automatic, but each line is set by from one to five microscopes, and the division traced by hand.

The other engine is that constructed by Messrs. Fauth & Co., of Washington, D. C., and is entirely automatic in its work. It is a fine piece of mechanical construction, and does honor to the constructors, and when compared with the original dividing engine of Ramsden, which I have examined, and which was a marvelous piece of work for its time, it tells unmistakably the advance of modern mechanical appliances in that direction. The *mean* error of a circle recently divided on this engine for the Cincinnati Observatory, as determined by Prof. Porter, is not greater than 1·0".

The heliometer is now playing a most important part in accurate astronomical measurements, and the work of Dr. Elkin, of the Yale University Observatory, and that of Dr. Gill, at the Cape of Good Hope, with this instrument, will, in all probability, give us a nearer approach to the absolute solar parallax than has yet been obtained; and this may be appreciated when you remember that the uncertainty lies in the 3d• decimal place of seconds of arc, a quantity altogether inappreciable to ordinary mortals.

This instrument has been largely used in a determination of the parallax of the "fixed" stars, and such

measurements are perhaps the most refined in the whole realm of astronomical studies, as no star has yet been found with a parallax greater than 0·9 second of arc, and most of those nearest to us are not greater than half that quantity. When it is considered that personal and instrumental errors must be eliminated for a period extending over one-half the earth's annual revolution, it is not to be wondered that in many cases the measure came out sometimes a plus, sometimes a minus quantity, with instruments used for the purpose before the heliometer was brought into requisition. I should like to describe this instrument, which indeed has been wrongly named, but time will not permit. I believe this instrument is made only by the Repsold Bros., in Hamburg, and I know of no one more competent to do such work of precision.

The astronomical camera is also adding largely to accurate astronomical measurements. It was thought at first that the shrinking of the film on the negatives would make stellar distances an uncertain factor, but no less an authority than Dr. Elkin asserts that the photographic charts of the Pleiades are as accurate for refined measurements as the stars themselves by the use of the heliometer, and whereas many of these stellar measurements have to be carried on for years under some of the most trying conditions, by the photographic method, a few hours will photograph all the stars of a group, or cluster, down to the sixteenth magnitude, and then the plate may be leisurely studied and measured in the laboratory without hindrance from cloud, bad definition, or the thousand and one difficulties the astronomer meets in endeavoring to reach his ideal.

The stellar charts given to us by those grand fellows, M.M. Paul and Prosper Henry, of Paris, by Prof. Pickering and his earnest corps of assistants in Southern California and Peru, as well as other members of the photographic congress; the beautiful photographs of nebula, by Dr. Janssen, of Meudon, Mr. Common and Mr. Roberts in England, and Dr. Von Gothard, in Hungary; the wonderful pictures of the solar surface made by Dr. Janssen, all show us the triumph of modern photographic manipulations. But the end is not yet. Commencing with the work of our own Dr. Draper and that of Dr. Huggins, we have spread before us to-day charts of stellar spectra which tell us of the physical constitution of those suns whose parallax is unknown, and whose light period may date back to the dawn of life upon the earth. It may be of interest to state that in this research, which has added so much to our knowledge of stellar spectra, the wives of Dr. Huggins and Dr. Draper have both assisted in the charming work, and although Dr. Draper has passed away, Mrs. Draper still carries on the work through Prof. Pickering, and Mrs. Huggins is still at her post at "Upper Tulse Hill."

One of the most wonderful results lately obtained in stellar spectrum photography is the discovery by Prof. Pickering that at certain regular intervals the K line in the spectrum of Zeta Ursa Majoris is doubled. The interpretation of this phenomenon is that the brighter component of this star is a close double star beyond the power of the telescope to separate, and that while the companion is rapidly rotating around the primary star, it displaces the lines one side or the other of the normal line, according as it is approaching or receding from the earth.

Two other stars have been discovered with this doubling of certain lines, and it would be difficult to predict what will be the result of future researches in this new field. I could dwell here for all the time at my disposal, but I dare not.

Time measurements in astronomical observatories have reached wonderful accuracy. When our big bell tolls the quadrant hours of the dial, we pull out our watches and are satisfied if we are within a quarter of a minute. Fortunately, our astronomer at the Allegheny Observatory is not so easily satisfied. If the stars will but shine, he is not content if the error be sixty times less, *i. e.*, a quarter of a second; and I recently saw the figures for several days' "time" work, where the errors were not greater than three one-hundredths of a second. We all know the great benefit of this time, transmitted to our railroad centers, and if human ingenuity could but have the trains keep time with the stars, we should never have the paradoxical phenomenon of two trains endeavoring to occupy the same track at the same time.

A recent instrument for accurate astronomical measurement, invented by Prof. S. P. Langley, and constructed at our works, is named by the inventor an occulting eye piece. Experiments have shown that the time of the occultation of a star may be readily determined with this instrument within one-twentieth of a second, and with experience the time may possibly be determined within one-fiftieth of a second, and this perfectly free from the element of personal equation.

In the construction of astronomical instruments greater and greater perfection is being reached in every decade, and the time has passed when the astronomical engineer is satisfied with "cut and try" methods as of old. The mathematician stands by him ever ready with the magic plus and minus to urge him on to higher attainments, to reach as near as possible to the demands of nature's unalterable laws. The object glass of the telescope, that marvelous eye that peers into the fathomless depths of stellar space, is now brought to most wonderful perfection, and has almost reached the limit of human possibilities. The refinement of the measurements of its curves may be slightly comprehended by the uninitiated when I say from personal knowledge and experience that the rubbing of a surface for a few seconds of time with the tip of the finger and the finest of polishing material may ruin the accurate performance of the glass. The measurements of the curves sometimes reach to the sixth decimal place, and the artist of to-day can determine so minute a quantity with great precision and certainty. In modern investigations of the object glass of the telescope, no one has done so much to bring it up to the highest standard of perfection as Dr. Charles S. Hastings, of Yale University. He has just completed some of the most refined studies in this line that have ever been made, and, perhaps, since the days of Gauss, no such advancement in mathematical dioptrics has been made, which, carried out experimentally, is now yielding most remarkable results.

The work of Alvan Clark & Sons in this line is known to all, their latest triumph being the great Lick telescope.

Paul and Prosper Henry and Secretan in France, Schroeder, Cooke, Hilger, Common and Calver in England, Sir Howard Grubb in Ireland, Merz and Mahler, Repsolds and others in Germany, and I might add other very honorable names to the list who have done a good part in this, one of the most charming fields of modern research, but I must not dwell here further than to mention that in our own country we are rapidly taking an important place in astronomical engineering.

The construction of the mounting of the great Lick equatorial was most successfully carried out by Messrs. Warner & Swasey of Cleveland, while the great telescope of twenty inches aperture is now well under way at the works of Mr. G. W. Saegmuller, of Washington, D. C., and both these firms have built and are now building smaller but no less perfect mountings for other observatories. It is hoped that we shall soon have standard dimensions introduced into all astronomical and physical instruments, and a movement has already been made in the right direction. It cannot come too soon.

In the realms of physical investigation and apparatus great accuracy has been reached in the past few years.

Let me mention one branch in which I have taken an humble part, namely, the production of optical surfaces for the ruling thereon of those marvelous diffraction gratings which have so greatly advanced the study of spectrum analysis. I can well remember when Nobert, of Pomerania, produced his first test bands for the microscope, and when he produced his first diffraction grating, which, in its entire ruled surface, was but two centimeters square. You will perhaps also call to mind the splendid work of Mr. Rutherfurd, of New York, who succeeded in ruling plates as large as one and three-quarter inches square, containing about thirty thousand lines, giving spectra of a hitherto unheard of sharpness and beauty. To-day we are producing surfaces fifteen centimeters square, in which the error of curvature or flatness, as the case may be, is less than one two-hundred-thousandth of an inch; and on which Prof. Rowland has ruled one hundred and ten thousand lines with such precision that the error between any two of the lines is probably less than one three-millionth of an inch. With this instrument of research physicists have boldly entered into new and untrodden regions of nature, and are from time to time uncovering her hidden wealth to enrich the storehouse of earthly knowledge. I present for your inspection the wonderful map of the spectrum of the sun which has been so recently placed in our possession by Prof. Rowland. Spread before you is the result produced by the use of the concave diffraction grating, untouched by the hand of man. In the red end of the spectrum, you see the marvelous B group, never before photographed as you see it now. Here you see the great C line and here the D lines, one of which is plainly double, while you see thirteen lines between the D lines. I can well remember when the instrument that would show the one nickel line between the D lines was considered a marvelous piece of work. Passing over the thousands upon thousands of lines between the D lines and the H line, we stop for a moment to examine between the H and K lines. Here is Angstrom's celebrated map of the solar spectrum. If you will examine it you will see he places three lines between H and K. In this photographic chart before you, I count one hundred and twenty-one lines between the H and K. But here Angstrom stops with his chart, because the human eye fails to see satisfactorily much further; but on this photographic chart we have, beyond the H K group, more lines than in the whole of Angstrom's map, as you see extending about thirteen feet on the photographic chart beyond that which is visible to the human eye, and containing thousands of lines. The value in wave lengths on these charts is given within one one-hundred-thousandth of its true position.

Probably one of the most refined studies in which the spectroscope is now being used is the determination of the stellar motion in the line of sight. No other instrument is as yet able to cope with this difficult problem. When a self-luminous body like a star is moving rapidly toward the earth, it is evident that it is advancing upon its own "waves" of radiant energy, thus shortening them. When it is receding from the earth, it is as it were running away from the waves of radiant energy it is giving out, thus in effect making all these waves of greater length. When its spectrum is examined in a powerful spectroscope, the absorption lines are seen to be shifted toward the violet, if the star is coming toward us; if the lines are displaced toward the red end of the spectrum, the star is receding from us, and by the amount of this displacement the velocity may be determined. This study, however, is a most difficult one, as at best the displacement is very small indeed, and it is only by the most refined and patient work that Mr. Christie, Astronomer Royal of the Greenwich Observatory, has given us our present knowledge of the motion of stars in the line of sight. Much is, however, to be hoped from the method of double displacement which Mr. Keeler expects to use with the great spectroscope of the Lick observatory. As also the photographic method already mentioned in connection with Prof. Pickering's work.

All this has been brought about by work of the highest character requiring refined measurements and manipulation of which our forefathers knew practically nothing. But the end is not yet. We are now constructing a machine called by its inventor, Prof. Albert Michelson, an "interferential refractometer," in which this same phenomena of interference is made the basis of measurement which lies close to the border land of human possibilities.

You are all aware that the various enlightened and civilized nations have standards of weight and measure that have slowly been evolved from the cubit, the span, the finger length and the barleycorn, if you please. Intimately associated with the evolution of standards of measurements are the names of Kater, Bailey, Bessel, Airy, Bird, Troughton, Babbage, Ramsden, Repsold and many others I could name; but in our modern work perhaps few men have done more than our own Prof. William A. Rogers, whom some of you know personally. I here submit to you one of his decimeter standards, in which we have included standards for the centimeter, millimeter, and hundredths of millimeters.

But, as I said, nations have their standards. On what are they based? The French meter is presumed to be one ten-millionth of the earth's quadrant, the English yard evolved from the barley corn, etc., but the measurements of precision in our day demand an indestructible, absolute, and unalterable basis for our standards, so that if they all be destroyed, the original is still available. Prof. Michelson has chosen a wave length of sodium light as the basis for a new standard, a something that will remain forever of the same absolute linear value, or, at least, so long as the solar system floats in the luminiferous ether that, so far as we know, pervades the entire universe. A wave length of sodium light is, roughly speaking, about one forty-two-thousandth of an inch long; or, better, five thousand eight hundred and ninety ten-millionths of a millimeter. Now, as this is an appreciable figure, it is evident that any method proposed to measure its *absolute* value must be of the highest accuracy.

The method devised by Prof. Michelson in the refractometer has certainly brought the work to marvelous perfection; for in a paper read by him at the Cleveland meeting of the American Association, he showed that the error was not greater than one part in two millions, and possibly would be made not greater than one in ten millions. Gentlemen, can you appreciate such a quantity? Yet here is a physicist, with a high ideal of perfection, taking the pulsations that are sent earthward by the sun, and by methods within the reach of human skill actually recording them upon a standard bar immersed in a freezing mixture, and giving us a universal standard based upon the absolute value of a wave length of light.

You may appreciate some of the niceties in the construction of this interferential refractometer when I tell you that in making some of the optical surfaces for use with it, Prof. Michelson demands an accuracy closely bordering on one-millionth of an inch.

With the new instrument Prof. Michelson proposes to carry out advanced experiments on studying the coefficients of expansion of standards, etc., the coefficients of elasticity, and critical measurements of the indices of refraction of various substances. But I must not dwell here, though the theme is as enchanting as fairy land. Nations have joined together for the production of standards of weights and measures, and but recently our government has received its new set, of which, I hope, we shall have a full description in the lecture we are to enjoy from Prof. Mendenhall on this very subject.

It may be of interest to you, however, to mention the fact that Prof. Wm. A. Rogers, formerly of Harvard observatory, has devoted the better part of his life in studying the errors of standards in use in this country and Europe, as well as producing some of the best work in this line that has ever yet been done. Perhaps no living man has worked so earnestly upon his hobby. For years he got out of his bed at five o'clock every morning to compare his bars of bronze, steel, copper, and glass, at an hour when they had swung through their oscillation or temperature changes, so as to be able to determine the absolute value of their coefficient of expansion, as well as to learn whether the material from which the standards were made passed through slow molecular changes or not. Among many important facts he has brought to light is that of the equable expansion of metals, etc., *i. e.*, that the expansion is equal for each degree within a range from zero to the boiling point, so that it is now only necessary to know the coefficient for one degree, and add or subtract from the standard temperature at which the bar was normal. In the production and ruling of these standards there are so many factors that come in as hindrances to perfect work, that Prof. Rogers must have added to his virtues that of patience to a very large degree.

I have no doubt some of our members call to mind his paper, read in Pittsburg some four or five years ago, before the National Association of Mechanical Engineers, on "A Solution of the Perfect Screw Problem." The great Whitworth said, "A perfect screw was never made," and perhaps he was correct; but Prof. Rogers has brought its solution about as close as any living man, except, perhaps, Prof. Rowland, who, indeed, makes the best screw possible by mechanical means, and then by studying its errors eliminates them by one of the most simple yet beautiful devices ever applied to the solution of so important a problem. Those of you who may be interested in this matter will find a most excellent article on the subject by Prof. Rowland under the title "Screw," in the ninth edition of the "Encyclopædia Britannica." I here take the liberty to show you a screw made under the supervision of Prof. Rogers in some of his earlier work. Its linear error is not greater than 0·00005 of an inch, but it has unfortunately a periodic error of drunkenness that makes it useless for the purpose for which it was designed, though for purposes where it can be used in whole revolutions it is, perhaps, equal to any ever made. It cost the labor of two of the best workmen of the Waltham Watch Tool Co. for 425 hours, at $1 per hour, so that it cost almost half its weight in gold.

One of the most delicate methods of studying a so-called perfect screw is to rule a diffraction grating by the aid of a diamond moved by the screw. If there are errors of drunkenness, as in this screw, the interference is so irregular on account of the overlapping of the spectra that no lines can be seen in the spectrum from the grating so ruled. If it is more nearly perfect, the imperfection is made known by false lines or ghosts in the spectrum, and, like Banquo's, they will not down until the errors of the screw are eliminated. There are many other methods of determining errors in the run of a screw, some of them of high value, and it is with considerable pride that I say our American machine shops are taking advantage of them to produce better and better work.

It needs no words from me to call to your mind the vast strides that are being made all around us in electrical science, nor is it my intention to elaborate upon the subject. But in connection with the theme of this paper, I may mention the great improvements being constantly made in the refined instruments for electrical measurements. When I call to mind the first induction coil made by Faraday, and which, only a year ago, I held in my own hands, I compare it with the beautiful and thoroughly practical instruments made within the sound of my voice. Is this not a marvelous age of improvement? Not only do we have our am-meters, our volt-meters, and our galvanometers measuring currents so minute as one hundred millionths of an ampere as well as the most enormous currents of electric energy, but made just across the way we have our electric meter, measuring out to you and me the

"subtle fluid" in quantities to suit our most fastidious tastes.

I may mention here that science is largely indebted to a little instrument called by its inventor the "bolometer" for some of the most charming discoveries ever made in the realms of radiant energy. It is essentially an electrical instrument, as its action depends upon the resistance to a feeble current by a most delicate strip of platinum, which when connected with a delicate galvanometer at once registers forms of energy coming to the earth from the sun, hitherto unknown, yet of so important a nature that did it not exist, life would not be possible upon this planet. It has brought us news from the sun and moon that gives new life to the study of what Prof. Langley has well named "The New Astronomy."

The delicacy of the measurements made with the bolometer may be appreciated when you learn that under certain conditions a deflection of one millimeter on the galvanometer scale is registered by a current of 0·000·000·000·5 (five billionths of an ampere) through the coils of 20 ohms resistance, and when the observing telescope is used on the divided scale, one-tenth of this deflection can be readily determined, and if we put this in temperature coefficients, one billionth of a degree Centrigrade can be indicated, while 0·000·001 of a degree may be indicated and measured.

It is with such an instrument that Prof. Langley has opened a new world to us, particularly in the infrared end of the spectrum, and has told us in the plainest terms that were it not for the invisible rays of radiant energy (invisible to the human eye), human life would be an unknown quantity upon the earth. But I must not dwell on these enchanted grounds, else I may be arrested by the fairies, who have no love for long-winded people.

In the domain of civil and mining engineering most of you are far better posted than I, and I would waste time were I to take too much of it rehearsing the improvements due to accurate work and measurements. Constant improvements have been made in engineering and mining instruments within the past decade, and I have been much pleased in my work as an instrument maker to receive some of the very best suggestions from our thoroughly practical engineers. Improvements in micrometers in use in geodetic work have been suggested that are of great value, and constant efforts are being made by our instrument makers to bring them up to the highest accuracy for measurement. In the United States coast and geodetic work the constant aim is for work of precision. As an instance, I may note a recent triangulation in southern California, eleven miles in extent, in which the mean error of three sets of observations was less than *one centimeter*. These observations were made by and under the direction of Prof. George Davidson, who was our representative at the late Paris Congress of Engineers. It is to be hoped that our esteemed head of the United States Coast Survey, Prof. Mendenhall, will use his best efforts to send such men to represent and carry out the work for our government when the nations shall again measure the Peruvian arc, as has already been proposed. We have advanced so far in our instrumental construction, in the character of our transits, theodolites, levels, heliographs, etc., that instruments of precision will not be lacking, if we can only furnish that important factor, the eye and brain at the small end of the instrument.

The accurate methods of alignments in the construction of long tunnels have been one of the wonders of the century. As I stood at the Swiss terminus of the great St. Gothard tunnel, my mind's eye carried me through its forty-nine thousand feet of solid rock excavation, executed by the hand of man, guided and directed by men of brains, alignment and levels measured and carried along from step to step until the diaphragm became thinner and thinner, and at last Italy and Switzerland shook hands over this triumph of modern engineering skill. The alignment proved to be true to ten centimeters for level and twenty centimeters for the lateral line. But engineers are not yet satisfied with their achievements. Only a week since I learned of a proposed method of optical alignment that in my opinion will be of the utmost value in work of precision. I should prefer to mention the method, but as its inventor has not yet brought it to perfection, I could not do so without a breach of trust.

Chemistry is also adding to its laurels in the domain of accurate analysis and work, and, indeed, while the spectroscope may detect the one three-millionth of a grain of sodium, we have yet to look to the chemist for those highly accurate determinations of quantitative analysis now so commonly characteristic of the modern chemical laboratory. The wonderful development of this beautiful science has perhaps contributed more than all others to supply the wants and necessities of the human race, and there is scarcely an industry to-day that is not in some way dependent upon the chemist for data upon which to carry on its work. So fully does this science enter into the industries of our own city, that every leading rolling mill and steel works has a completely equipped laboratory and practical chemist, to supply from time to time accurate analysis of their products. Further than this, some of our own honored members are earnestly working toward that which must come sooner or later, namely, standard chemical equivalents in the various grades of steel and iron. Let us give them our earnest support in this important work.

In mechanical appliances and in modern machine work great strides are being constantly made toward greater and greater perfection, and as I said in the outset, the mechanic of to-day is not satisfied with the coarse measures and gauges of our early days; but he must have his steel graduated rules, his micrometer calipers, his standard end gauges, his standard reamers, etc. What the English nation owes to their Whitworth, we, in turn, owe to such firms as Brown & Sharp, Pratt & Whitney, Sellers, Bement, Warner & Swasey, and others for their valuable contributions to metrology, and their standards of various kinds that have contributed so much to advance mechanics in this country. The standard measuring devices made by Brown & Sharp, including their micrometer caliper, micrometer gauges, Vernier calipers, etc., their hardened steel squares and angles, etc., have become a power for accurate work. I notice it particularly in my own works, where my own excellent workmen have a most laudable ambition to read to the finest possible quantities in their mechanical manipulations, and, as a consequence, we are brought nearer and nearer to that devoutly to be wished for millenium when interchangeable parts will be the *rule* and not the exception. The standard gauges, reamers, taps, and dies of the Pratt & Whitney Company now find an honored place in all high-class machine shops; and our American machinists are greatly indebted to the labors of Prof. W. A. Rogers and Mr. George M. Bond, who designed and carried into execution that wonderful instrument of precision called the Rogers-Bond comparator, from which has emanated so many standard tools, and which has assisted so largely in the introduction of interchangable parts in American machinery. Every advanced machinist should read the admirable work published by this company, and edited by Mr. Bond, on standards of length. I am not saying this as an advertisement of any firm, but wish to give credit to our Yankee brethren who have done so much for work of precision in the machine shops of this great country.

But we have yet much to do to bring up mechanical work to the standard it should be brought to. A few of our best shops have their tool room, and a competent man in charge of it, but the day will come when the comparator will be in every tool room, when records in thousandths of an inch will be kept of the size of every important piece of machinery. The mechanic in charge will adjust every gauge and caliper by the comparator, and hold the workman responsible for his work. Watt thought he had attained remarkable accuracy when he bored one of his cylinders so that he could not get half a crown between the cylinder and piston head. But we are not living in Watt's time, nor in the age of the old Cornish engine; and although we are not to despise the days of Watt and the Cornish engine, we have no excuse, in this advanced and enlightened age, to turn out indifferent work of any kind. Nor is it necessary to dwell on the importance of this accuracy of work in our machine manipulations, for while we have not yet reached an universal standard of interchangeable parts in our machines, every important firm in this country is doing a good share in advancing the grade of their output, and in good time we have reason to believe that precision will take the place of carelessness, and that excellent "rule of three" instead of that ancient and dishonorable "rule of thumb."

It is true that human hands and human brains must have a limit to their capabilities; but where shall we place that limit? Watt gave us the horse power as a unit of measurement, Joule gave us the better one of the foot pound unit, King Henry's arm may have served for the long measure, and the barleycorn for the short measure, but the meter and the micron are infinitely superior, yet we still hope for better standards, and are now reaching out for waves of radiant energy from which to make them, and which shall remain as constant as the universe, "whose builder and maker is God."

In the realms of the higher sciences the mind of man has reached, as it would seem, almost to the infinite. The mind may think and think, but human ingenuity is surrounded with so many hindering environments that it cannot execute the commands of the brain; but we can approach to that boundary line where the sign board tells us, in unmistakable characters, "Thus far shalt thou come, but no farther."

Sir Wm. Thomson has estimated the size of the molecule to be somewhere between one two-hundred-and-fifty-millionth of an inch and one five-billionth of an inch, and in that beautiful illustration familiar to most of you, tells us "if a drop of water were magnified to the diameter of the earth and the molecules magnified in the same proportion, that the smallest as noted would be coarser grained than a heap of small shot and the largest less in diameter than a heap of cricket balls." Can we therefore ever hope to deal with such infinitesimal quantities? Possibly, probably not, and yet who can tell what a day may bring forth? The organs of sense in man have some marvelous capabilities. The human retinal nerves, for instance, have astonishing powers of discrimination. Prof. Rood has shown that a flash of light lasting but forty billionths of a second is capable of making an impression upon the human retina. Prof. Langley has shown in his charming monograph on "Energy and Vision" that the visual effect produced by any given constant amount of energy varies enormously with the color or wave length producing it, and that while we may perceive a white light in so short a time as Prof. Rood has shown, yet for the actual physiological processes required in seeing, we require from one-quarter to one-half a second. He then shows that the *vis viva* of the waves of light whose length is 0·75 microns long when arrested by the human retina, *represents* work done in giving rise to the sensation of crimson of light, of 0·000·000·000·0003, or three ten-trillions of a horse power, or about 0·001 one thousandth of an erg, while the sensation of green can be produced by 0·000·000·001, or one hundred millionth of an erg.

Moreover, he has shown that the human eye has a vast range in the intensities of lights it can perceive, represented by the ratio of 1 to 1,000,000,000,000,000, or one to one quadrillion. Prof. Nichol has also shown that some human eyes are capable of discriminating tints of color so rigorously as to detect one part of coloring matter in one hundred million parts of white. Here, then, I have given you a few instances of the remarkable powers of one organ of the human economy, an organ that we use so constantly in all our refined measures and manipulations. Who then can tell the limits of human capabilities for grand achievements in the future? The world's great workshop is open for all of us. She needs master workmen. As the laws of Mother Nature are more unalterable than those of the Medes and Persians—and if we shall pursue our work in conformity to their demands, so shall we make progress toward perfection, and although the goal may never be reached, there is a happiness and triumph in knowing that we have taken steps in advance of those before us, and have set the example of patience and progress to those who will follow after us.

Let us then be up and doing,
With a heart for any fate.
Still achieving, still pursuing,
Learn to labor and to wait.

IN the treatment of tumors by electricity it has been pointed out that extreme care is necessary, especially when negative electricity is used.

ON THE GENESIS OF ELEMENTS.

By H. M. VERNON.

SINCE the time when Prout first formulated his hypothesis of the genesis of the elements from the primordial atom, there has always been a feeling in the minds of chemists that this hypothesis may possibly in some future time be verified experimentally, at least to a certain degree. This feeling has been strengthened during the last few years by the discoveries of Crookes and other chemists, of what have been termed the meta elements. Crookes, starting from a specimen of mineral supposed to contain only one or two rare earths, has succeeded by a laborious process of fractionation in resolving one of these earths, supposed to be the oxide of a single element, into several other earths, all of which have properties almost exactly similar, and only capable of being distinguished in some cases by the difference in their colors or by the difference of a single line in their spectra. These earths are the oxides of elements of scarcely perceptibly different atomic weights, for all of which it would not seem possible to provide a place in the table of elements arranged according to Mendeleeff's periodic law.

Arguing from these discoveries, Crookes asks whether it may not be possible by suitable methods of fractionation to separate many, if not all, of the rest of the so-called elements into a number of other elements almost exactly similar in properties and in atomic weights, and thus to obtain an almost infinite series of elements, the properties of which gradually change in regular order as they pass through the cycles of the series of elements arranged according to the periodic law.

Many almost insurmountable difficulties, which it will be unnecessary to enumerate, have been brought against this chain of reasoning by various chemists. This hypothesis, being for the present, at least, therefore considered unacceptable, we come to the question as to whether there is no other hypothesis that has the same end in view which is capable of being formulated, such that may appeal more readily to the minds of chemists. It is with this object in view that these few ideas have been brought forward.

At the beginning of the universe we may consider it very probable that there existed only the primordial atom, which has in the course of ages become gradually cooled down, united among itself to form the complete cycle of elements as known to us at the present day. Those elements most stable as regards heat would first be formed as this process of cooling went on, while those least stable with regard to heat would be formed last, all elements but the first being formed by the addition of other primordial atoms to the elements already formed.

If this be the case, we may conversely regard it possible to disintegrate some at least of the so-called elements into bodies more simple than themselves, that is, into bodies more stable as regards heat, by heating them to a sufficiently high temperature. If, indeed, a high enough temperature could be obtained, it would be possible to disintegrate all the elements known to us into not only simpler bodies than themselves, but into the primordial atom from which all the elements were originally formed.

The question now comes whether it will be possible to obtain the extremely high temperature necessary for this purpose. The reply is that, as far as can be seen, there is no possibility of ever reaching a temperature high enough to decompose an element into its primordial atoms; but that it may be possible to reach a temperature high enough at least to decompose some of the elements least stable as regards heat into bodies more stable with regard to heat than themselves.

The reason for this reply is that the only practicable means we have for obtaining high degrees of temperation are (1) utilizing the heat evolved by the combinature of bodies with each other and (2) by means of electricity.

It is obvious that only a certain degree of temperature can be obtained by the first method, as the compounds formed by the combination would be incapable of existing above this temperature, and therefore no combination would take place, as there would be no affinity between the bodies.

In the case of electricity also, as far as may be judged, it is only possible to obtain a certain degree of temperature. We may therefore ask whether it is not possible by any other means than direct experiment to ascertain whether so-called elements cannot be decomposed into bodies simpler than themselves by the action of heat.

By means of the spectroscope it has been found possible to ascertain the presence of many of the elements in the sun, and to a certain extent those present in the fixed stars.

The temperature of the sun is admittedly very high. Is it not possible that it is high enough to have caused some of our least stable elements to have been disintegrated into more simple bodies?

Of the elements known to us, about half have up to the present been shown by Thalén, Lockyer, and others to exist with more or less probability in the sun. The proofs of the presence of some of these elements depend upon the coincidence of only a very few lines of the sun's spectrum with those of their spectra as known to us; their presence may, however, be provisionally accepted.

If these elements be arranged in order of their atomic weights according to Mendeleeff's periodic law, the places of the elements whose presence in the sun has not been proved being left as blanks, we obtain the following table:

Groups.	1	2	3	4	5	6	7	8		
1.	H									
2.	Li	Be								
3.	Na	Mg	Al							
4.	K	Ca	—	Ti	V	Cr	Mn	Fe	Co	Ni
5.	Cu	Zn		—						
6.	Rb	Sr	Y			Mo	—	Ru		Pd
7.	Ag	Cd	In	Sn			—			
8.	Cs	Ba	Ce	La	—					
9.	—	—	Er	—			—	Ir		Pt
10.				Pb	Bi	—	—			
11.	—	—	—		—	U	—			

From this table we see that almost all the most positive elements are present, but, that as the elements be-

come more and more negative, fewer and fewer appear capable of existing in the sun's photosphere. Thus no less than eight of the elements occurring in the first group and seven of those in the second group have been shown to be present. When, however, we come to the third group, in which the elements are of a more negative character, their instability with regard to heat becomes more marked, only five of them being found to be present. Only four of the elements of the fourth group are found to be present, and of the fifth group only two; of the sixth group three elements apparently are present, while of the seventh group manganese is the solitary representative. The eighth or extra group of the table is very well represented, probably seven, if not more, of the elements occurring in this group being present. Of these elements, too, iron and nickel occur in the sun in quantities as great as almost any other element. The behavior of this group is therefore abnormal in very much the same way as it is in the arrangement of elements according to the periodic law.

We therefore find with striking regularity that as we proceed from the left hand group of positive elements to the right hand group of negative elements in Mendeleeff's table, the number of elements of each group found to exist in the sun's photosphere decreases proportionately to the increase of negative properties of the elements of each group taken as a whole.

If, now, it be granted that the majority, at any rate, of the other known elements are not present because they are decomposed by the high temperature of the sun into bodies simpler (that is, more stable in regard to heat) than themselves, we find, as a rule of general applicability, "*that as we pass from positive to negative elements, the stability of the elements with regard to heat decreases proportionately as their negativity increases.*"

We see from the above table that it is not merely that non-metallic elements taken as a whole are less stable with regard to heat than metals, but that elements, whether metal or non-metals, are stable with regard to heat or the reverse according to their positivity.

The fact that no non-metallic elements appear in the table, unless we except hydrogen, would show that these bodies taken as a whole are much less stable with regard to heat than the metals. This is quite borne out by what is otherwise known of their behavior when subjected to moderately high temperatures. Thus almost all the non-metallic elements which have been volatilized have been found to possess simpler molecules at higher than at lower temperatures. The molecule of sulphur at 450° C. contains six atoms, while at 800° C. it contains only two. At a still higher temperature it would probably contain only one.

Phosphorus and arsenic at a red heat contain four atoms in their molecules, while at a white heat they contain only two. Up to moderately high temperatures the molecules of bromine and iodine contain two atoms, but at 1,800° the molecule of bromine and at 1,500° the molecule of iodine contain only one atom. At a still higher temperature chlorine would probably act in a similar manner. Even in the case of the non-metals carbon, boron, and silicon, which have not been volatilized, it has been shown by Weber with a considerable amount of certainty that the constitution of these elements is much more complex at lower than at higher temperatures. This follows from the fact of their specific heats being very much greater at higher than at lower temperatures; thus the specific heat of the diamond at 985° C. is about seven times greater than it is at—50°, so probably the molecule of diamond at a temperature slightly below this contains eight times as many atoms as the molecule at 985° C. Very much the same thing will hold in the case of boron and silicon. If, then, as is shown by these facts, the molecules of the non-metallic elements are more simple at higher than at lower temperatures, it would seem very probable that at higher temperatures still their constitution would become still more simple, that is, they would be split up into other bodies, which bodies might very possibly be some of the more stable elements at present known to us.

When we examine the constitution of the gaseous molecules of some of the metals, we find their behavior to be totally different from that of the non-metals. The molecules of all the metallic elements at present examined are found to contain one atom, and one atom only, whatever be the temperature to which they are subjected. The metals which have been examined so far are sodium, potassium, zinc, cadmium, and mercury. All these elements, except mercury, have been found to exist in the sun, and it has not been conclusively proved that this element is not present.

If the vapor densities of other metals were taken, it would very probably be found that at all temperatures the molecules of the more positive metals contained only one atom, but that as they began to develop negative properties their molecules would be more complex at lower than at higher temperatures, thus indicating that at higher temperatures still, such as that of the sun, they would probably dissociate into still more simple bodies, that is, that they would cease to exist in the form of the original elements, but would be changed to some other bodies more stable with regard to heat.

At a temperature still higher than that of the sun, it would be reasonable to suppose that a still smaller number of elements would be capable of existing as such. As a proof of this supposition, it has been shown by Huggins and others that the constitution of the white, and therefore presumably hottest, stars is exceedingly simple, their spectra containing only a few lines and therefore showing the presence of only a very few different kinds of matter.

From the above results may we not conclude that there is a possibility, if not a likelihood, of our arriving at some knowledge of the genesis of elements by endeavoring more exactly to ascertain the temperature of the sun and the elements forming it, and also by endeavoring to split up some of the least stable of the elements, as known to us, by the action of heat? If it were possible to ascertain the variations in the temperature of the sun at different points of its photosphere and chromosphere (and it is very probable that it varies enormously), and also the composition of the vapors at these points, it might be possible to arrive at a rough conclusion as to the elements which were capable of existing as such at various temperatures and those which were not.

CURIOUS PROCESS OF CUTTING AN ORANGE SKIN.

WE illustrate in Fig. 2 a number of curious shapes into which the skin of an orange can be carved after a particular tracing (Fig. 1) and then be spread out in its entirety, without a break.

The process is as follows:

An orange is selected that has as few flaws in the skin as possible. It should not be divided in the center into too large a number of parts; eight is a convenient number. The lines shown in Fig. 1 may be drawn on the skin with a pen and ink, and this will make the work of cutting easier. This done, take a very sharp knife and incise the skin according to the marked lines. In measure as the incisions are made, raise the skin carefully, then detach it completely, and spread it out upon a board, and pin it thereto in order that it may dry (Fig. 4). It is well to draw a few concentric circles upon the board and divide them into eight or sixteen radii, in order that the skin may be spread out in a very regular figure.

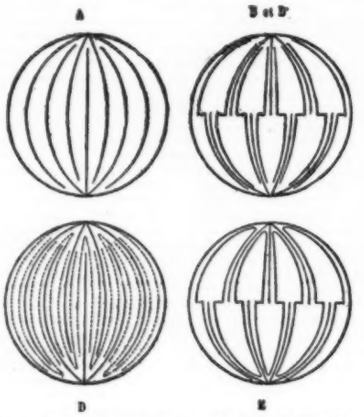


FIG. 1.—PATTERNS DRAWN UPON AN ORANGE SKIN.

Fig. 1 gives the lines that produced the forms shown in Fig. 2. The letters in the two figures correspond.

A and B are quite simple forms. B' forms a remarkable belt, and C, in the center of it, represents the proportion in size of the orange from which it was made. The three figures, D, E, and F, are of remarkable delicacy.—*La Nature.*

PALENQUE, THE AMERICAN POMPEII.

WITHOUT doubt the buried city of Palenque is the most interesting ruin in America, if not in the world. The very race and language of the people who built it are lost, and no one has yet interpreted the curious hieroglyphics which cover its massive walls. Here are ruins showing a degree of engineering skill which closely resembles that of the ancient Egyptians. Perhaps the strangest thing connected with this extraordinary place is the fact that antiquarians and Egyptologists have never investigated these ruins or sought to interpret these numerous graven records of a great though long forgotten race.

Among the most interesting and extensive ruins of the cities of those mysterious races who antedate the Spanish invasion of Central America, and whose history is carved in the symbols of an unknown tongue on many tablets and monuments of stone, are those of Palenque, which is on the ninety-second meridian west of Greenwich and in about 17 degrees 29 minutes north latitude, in Chiapas, on the border lands of old Mexico and Yucatan.

Palenque was visited by nearly a half score of travelers before its exploration under competent direction was attempted in 1340 by Stephens and Catherwood. But they reached the site at the beginning of the rainy season, at the end of a journey of extraordinary difficulty, full of hardship and disaster, and conducted their researches under quite as discouraging conditions as did any of their predecessors. Since then there has been no effort whatever to bring to light the archæological riches of this wonderful ruin.

The work of exploration was done with extraordinary intelligence and thoroughness under the circumstances, and a wise discretion was undoubtedly exercised in the selection of the subjects for description and illustration, but the explorers turned away at last with hearts full of regret over their inability to lay bare more than the most prominent and easiest accessible features of the vast monumental piles that form the ruins of what must once have been the center of a dense and intelligent, if even a morally hopeless, degenerate population. Stephens says: "We were exceedingly anxious to make excavations, clear out the rubbish, and lay the whole platform bare, but this was impossible. It is probably paved with stones or cement, and from the profusion of ornament in other parts there is reason to believe that many curious and interesting specimens may be brought to light. This agreeable work is left for the future traveler, who may go there better prepared with men and materials and with more knowledge of what he has to encounter."

Palenque was accidentally stumbled upon by a party of Spaniards who were traveling in the interior of

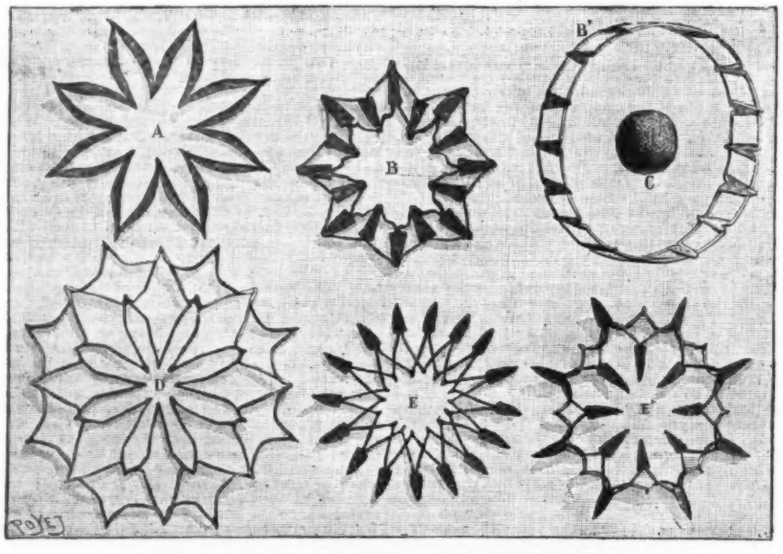


FIG. 2.—FIGURES OBTAINED FROM ORANGE SKIN.

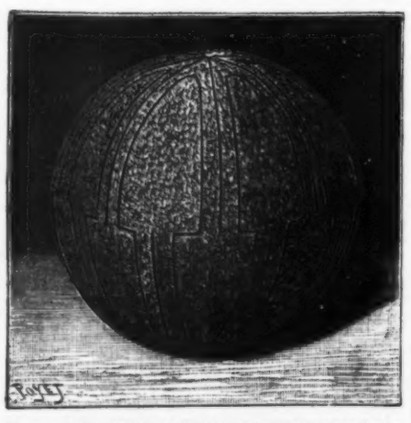


FIG. 3.—FIGURE DRAWN UPON AN ORANGE SKIN BEFORE CUTTING IT.

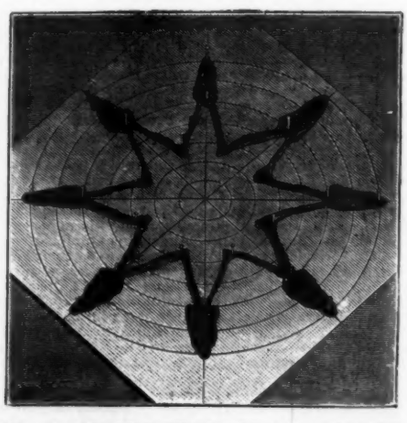


FIG. 4.—ORANGE SKIN CUT AND SPREAD OUT ON A BOARD.

Mexico in 1750. They had wandered in search of things new and strange, into the region north of Chiapas, when they all at once found in the midst of a vast solitude ancient stone buildings, the remains of a vast city, still embracing from eighteen to twenty-four miles in extent, and known to the Indians by the name Casas de Piedras. The Indians themselves could give no account of its origin. To this day it is not known by what name it was called, and the name given to it, Palenque, is taken from the village near which the ruins stand. Two exploring parties sent out by Spain, one under Capt. Del Rio, in 1787, the other under Capt. Duplaix, in 1805-6-7, made reports upon the Palenque ruins, which reports were published in 1822 and 1835, respectively, too long after the work of exploration to accomplish any desirable result.

When visited by the American explorers the ruins were overgrown with so dense a forest of gigantic trees and tangled undergrowth that a person ten yards distant in any direction could not be seen. And having no axes or shovels or spades, but only the machete—a short, broad-bladed sword of the Indians—with which to clear away this accumulation of centuries of luxuriant vegetable growth, but little, compared with the entire task, could be accomplished.

Fine buildings, constructed of stone, with a mortar of lime and sand, were found here, the outer walls of which were covered with stucco and painted. The principal of these structures was the so-called palace. It faces the east and measures 228 feet front by 180 feet deep. It stands on an artificial elevation 40 feet high, 310 feet in front and rear, and 260 feet on each side. This elevation was originally faced with stone, but the crowding vegetation has left naught but the foundations standing. The palace is not more than 25 feet high, but it is rendered very imposing by a broad projecting cornice of stone. The front is pierced by 14 arched doorways, about nine feet wide each, and the intervening piers are between six and seven feet wide. The piers which remain standing are ornamented with figures in bass-relief and with intaglio inscriptions in hieroglyphics. In some of these the remains of red, blue, yellow, black, and white pigments were discovered. The figures, usually drawn or engraved in profile, are of persons, male and female, in attitudes of worship generally, but always in posture of worship, clad fantastically and ornamented with indescribable head dresses, necklaces, and jeweled regalia. Every tablet contains an inscription in symbols of the forgotten tongue, which, if it could be read, would probably tell the history of the picture. The palace was divided and partitioned by interior walls of masonry into a multiplicity of small rooms opening upon interior courts, of which there were four. In one of the rooms was an elaborately carved altar of stone; in another there were sculptured tablets; and on the east and west sides of a court 80×70 feet in area, in the northeast quarter of the palace, were large tablets of hieroglyphics, colossal figures in relief, and smaller figures of females richly robed and ornamented, but crouching in attitudes expressive of fear and terror.

Adjoining the palace on the southeast corner is a structure standing on a pyramid 110 feet high on the slope. It is 76 feet long and 25 feet deep and about 30 feet high. It has five doorways and six piers, all standing, topped by a wide cornice of stone, with a roof that is shaped much like a Mansard roof of recent architectural design. The whole front is richly ornamented in stucco, and the corner piers are covered with hieroglyphics, each containing ninety-six squares. On the interior walls are three tables of hieroglyphic inscriptions, carved in symmetrical lines out of stone. One was only about half finished when the work was arrested forever by the unknown catastrophe that came "like a thief in the night" and obliterated the race of builders and all knowledge of their literature. The solution of these inscriptions would in all probability shed the light of truth upon the dark mystery of the origin and history of the ruins and their builders, and might reveal things that are more interesting and important from an ethnic point of view than the discoveries at Herculaneum and Pompeii. The hieroglyphics are of a similar character to those found at Copan and Quirigua, indicating that they were engraved by the same race of people.

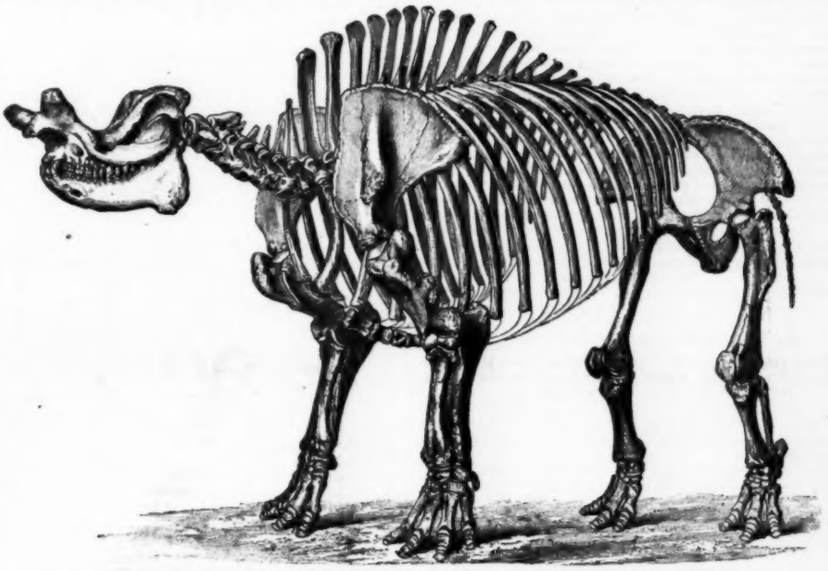
Remains of an aqueduct by which the city was supplied with water from a stream close by adjoin this ruin, and further on is a broken stone terrace, about 60 feet on the slope, with a level esplanade from which rises another pyramid, now overgrown with trees. It is 134 feet high on the slope, and on its summit is another stone building 50 feet wide and 31 feet deep, having three square doorways in front, but no other openings. The building faces the south, contains three chambers within each other, and sculptured ornaments and hieroglyphics inside and out. In the inner chamber there is an altar, and over the altar on the wall a remarkable sculpture in bass-relief. Central in the picture is a richly carved cross, a very significant figure in this place, surmounted by an apparently deified bird. On either side of the cross are a man and woman standing in the attitude of offering sacrifice to the bird deity. A tablet containing over a hundred hieroglyphic inscriptions occupies a third of the space on the left, and undoubtedly relates to the graven picture. The remaining buildings are similar in character to those which have been described. And in the dense forest that has overgrown the site of the ancient city are hidden deep from the gaze of man as many and as important objects of archæological interest as any that have yet been disclosed. But one statue was discovered, that of a female figure, 10 feet 6 inches high, and more resembling Egyptian portrait statuary than anything else discovered in this new "Old World." But it is a sufficient promise of other statues and monuments in the depths of the forests round about. Where these great monolithic idols came from, how they were taken from the quarry, how transported and erected, with what instruments they were sculptured, and the thousand collateral and connected questions relating to the designers and the builders of the massive structures round about, are questions of the keenest interest that call louder for solution than any other unsolved problem of history, and are yet hidden in the depths of the forest that year by year are deepening the oblivion in which they will be eventually forever lost past all human power of resurrection. Unless the probe of science be soon applied, these treasures of antiquity will slip forever from the grasp of civilization.—*Eng. and Min. Jour.*

TITANOTHERIUM IN THE BRITISH MUSEUM.

To those English zoologists who have not had the good fortune to visit the paleontological museums of the United States the huge Miocene mammals forming the family *Titanotheriidæ* have been hitherto known only by description and small-sized figures of the skull and skeleton, which, however excellent they may be, afforded but a very inadequate idea of the proportions of these most remarkable Perissodactyle Ungulates. Recently, however, Prof. O. C. Marsh, of New Haven, to whose generosity our national museum is already much indebted, has presented that institution with a beautifully executed model of the skull of one of these mighty brutes, which is now exhibited in the front paleontological gallery, below the head of the skeleton of the Kentucky mastodon. By singular good fortune the keeper of the geological department of the museum has been enabled at the same time to purchase associated examples of the teeth of another member of the family, which are placed alongside of the cast, and thus enable us to see the actual state of preservation in which the remains of these creatures are found.

The *Titanotheriidæ* were first made known to science from the evidence of specimens of the dentition described years ago by the French naturalist Pomel, by whom the name *Menodus* was proposed for their owner. Unluckily, however, this name was preoccupied by the earlier *Menodon;* and we are therefore compelled to adopt for the type member of the family the name *Titanotherium*, which is the first of the numerous terms proposed by American writers. The species of which the skull has been presented to the museum is made by Prof. Marsh the type of a distinct genus under the name of *Brontops*.

The chief distinction of this form from the type of *Brontotherium*, which seems inseparable from *Titanotherium*, appears to be the reduced number of incisors, but if writers like the director of the museum are right in regarding such variations in the allied group of the rhinoceros as of not more than specific importance, this species should be included in the type genus.



RESTORATION OF THE SKELETON OF TITANOTHERIUM ROBUSTUM.

(1/12 nat. size.) After Marsh.

These Titanotherioids appear to have been most nearly allied to the rhinoceroses among existing forms, as is at once apparent from the contour of the skull. According to Prof. Marsh, they were larger than the Dinocerata of the Eocene, and nearly equaled in size the existing elephants. The skull differs from those of the rhinoceroses, however, in that, instead of having one or two horns placed in the middle line of the nasal region, and having no sort of bony connection with the skull itself, it has two large processes of solid bone in a transverse line immediately over the nose, which were probably invested with a horny sheath.

The molar teeth are, moreover, unlike those of the rhinoceroses, having excessively low crowns, and an arrangement of the tubercles and ridges very similar to that obtaining in the Tertiary genera *Limnohyus* and *Chalicotherium;* the first of which is certainly, and the latter probably, a Perissodactyle, although the recent discovery that the peculiar claws upon the evidence of which the supposed Edentate genus *Macrotherium* was founded are referable to it, renders it a most aberrant type.

The skeleton to which the original of the cast presented to the museum pertains was found in 1874 by the donor in those beds of the Dakota Miocene known as the Brontotherium beds, and it appears to be the best preserved example yet known. A restoration is given in the accompanying woodcut. According to Prof. Marsh, these deposits are several hundred feet in thickness, and may be separated into horizons, characterized by peculiar species of *Titanotheriidæ*. The remains of several hundred individuals of this exclusively American group have already been secured by the paleontologists of New Haven, and their English *confreres* look forward to the publication of the sumptuous monograph in which Prof. Marsh promises to illustrate these specimens with much interest.—*Nature.*

LONG ago Florence Nightingale declared all hangings in living rooms to be unwholesome, and ordered even window drapery to be removed from the sick room, no matter what name might be given to the disease of the sufferer.

A CUTTLE BONE.

TO-DAY, a friend who is by no means curiously inclined regarding science at large brought me an object which he alleged he had purloined from the cage of a canary bird in the house of an acquaintance. Curiosity had for once got the upper hand of him, and after a hot discussion with the owner of the cage and bird regarding the nature of the object in question, my friend seized the article in question and bore it off in triumph for elucidation on my part. The object was a plate of lime—to be strictly correct, of carbonate of lime, or in plain language, chalk. It was of oval shape, about four or five inches long, convex on one side and flattened on the other. More closely inspected, it was seen to be made up of layers of limy matter, superimposed one on the other. This object is familiar enough, as I assured my friend, in every bird dealer's emporium. It is hung in the cages of birds that they may peck at it, and obtain therefrom the limy materials which are essential for their health, especially in reference to the laying of eggs and the due formation of the shell. The bird owner had assured my friend that the object was a "cuttlefish bone;" and so, doubting the science of his acquaintance, he bore off the disputed article to me, thinking that a zoological opinion on the matter might be worth having. Under the common name of the cuttlefish bone, it is perfectly true, the limy plate is sold. It still makes its appearance in pharmacy (being used for tooth powder) under that name; although it is not in any sense a bone, and although a cuttlefish, to begin with, is not a skeleton-possessing animal.

To begin with (as I informed my friend), he must first of all turn his attention to cuttlefishes at large. In the Brighton Aquarium or elsewhere he had seen the *Octopus*, and on the sea beach at Dawlish he had picked up the dead bodies of numerous *Sepias*, which are near cousins to the "devil fish" itself. Octopus and sepia are both very typical cuttlefishes, and the list might, of course, be greatly enlarged. There are the squids, or *Loligos*, with their arrow-shaped tail-fins and their elongated bodies; and there is the argonaut, or paper nautilus, and the pearly nautilus, with its distinct shell, familiar, when polished, to everybody as a drawing room flower vase. This, then, was my first proceeding in the case of the "cuttlefish bone"—so called—to instruct my friend in the nature and forms of the cuttlefishes. This done, the next step consisted in my reminding him that these animals are *Mollusks*—that is to say, they are relatives of the snails, oysters, mussels, *et hoc genus omne*. In a word, cuttlefishes are shell fish, properly so designated. They stand at the head of the molluscan group, just as quadrupeds (including *homo sapiens*) stand at the top of the backboned type of animal life. This remark settles the position of the octopus and its neighbors in the animal scale, and shows that they are true shell fish by right of birth and by all the lawful titles which a distinct zoological position can confer. Bones, it is true, they have none, for these structures are the exclusive possession of the backboned group; hence, if the limy plate found in the canary's cage proved (as prove it did) to be a cuttlefish belonging, it is clear that to call it a "bone" was a contradiction in terms.

The limy plate is not a bone, but a shell. Unlike a shell in every respect, it nevertheless duly represents, in the sepia cuttlefish, the familiar structure we see in the snail or the oyster. We know this, first of all, because it is made by that part of the animal which in other mollusks, and also in other cuttlefishes, manufactures the shell. This is the outer layer, or integument of the body, which in natural history language we call the "mantle." Whatever structures this layer forms and secretes are shells, in the true sense of the term. The objects it manufactures, like the shell of the sepia cuttlefish itself, may be utterly unlike shells. As such, they may not be recognized at all; yet in their nature they are shells nevertheless. If we turn for a moment to two other cuttlefishes, we may be able to prove this assertion very easily. There is a cuttlefish, extremely rare indeed as a living animal, but whose shells, as I have remarked, are common enough in drawing rooms. This is the pearly nautilus. It is like the last of the Mohicans, in that it is the sole survivor of a once large group of shell-possessing, four-gilled forms. Its shell is of very perfect character. It is divided into compartments, each of which the animal successively in-

habits. As it grows too big for its receptacle, it partitions off the old apartment, and adds a new room to its house, living in the last formed and biggest of the rooms. Now, this perfect shell of the pearly nautilus is made by the mantle, just as the shell of the snail or oyster is fabricated by that layer of the molluscan body.

Turn we now to the argonaut, or paper nautilus. Here, also, we find a shell; but it is not formed by the mantle of the animal. The delicate, papery shell of the argonaut is made by two of the arms of the animal, and therefore does not agree with the true shell of the other nautilus. Cuttlefishes, however, have undergone a very large amount of modification as living forms. To-day it is the sepias and the octopi and their kith and kin which swarm in the seas. They are active, free-swimming animals, which do not depend on a shell for protection, as does the pearly nautilus of to-day, or as did the old extinct and fossil allies of the last named animal. They are wary and agile in all their movements, and have apparently got rid of their shells entirely, just as the slug of the garden has relinquished his shell (seen in his young state), while his neighbor the snail has retained that possession of molluscan life. Yet closer examination reveals that the sepia and octopus and other modern cuttlefishes have not wholly surrendered their shell-making instinct; for, lying on their backs, embedded in their mantles, we find shells of rudimenary description. This shell in sepia is the cuttle-bone of the bird shop and the drug store. It is a lingering remnant of shells which, once upon a time, were very well developed in the ancestors of the sepia and its friends. It has dwindled away till it has become a mere plate of lime, bearing faint and feeble traces of a once complex structure. In the squids or loligos, which are used so largely for bait by the Newfoundland fishermen, the shell has become degraded until it forms a mere horny pen. So that what my friend purloined from the canary's cage is really a curious example of a shell that has gone to the wall in the struggle for existence, simply because it was not needed in the life and wants of the modern cuttlefishes.

This much is certain from ordinary natural history science alone. If, however, we were inclined to doubt the correctness of the inferences we have drawn, we should be able to find additional proofs in the shape of other cuttlefishes. The extinct belemnites are cuttlefishes in which the shell had become internal, while still retaining many of the characters of an outside shell. In the little living spirula the shell is becoming internal. So that we have all the stages at command, showing us how an outside shell in these animals has become internal, how it has become further degraded, how it has attained to a yet more elementary structure, and finally how, being no longer needed by the animal, its makes its appearance in the guise of a mere plate of lime, gathered from the sea beach to feed our birds with their mineral food under the name of the cuttle-bone.—*Andrew Wilson, Ill. London News.*

THE PHYSIOLOGICAL TREATMENT OF OBESITY.*

By WALTER MENDELSON, M.D., New York.

THE practice of medicine is—even at its best—so empirical an art, the limitations of our best endeavors, when measured by our aspirations, are everywhere so narrow, that we should always be prepared to hail with joy any one department in which we discern *some* prospect of advancing with anything like scientific accuracy.

Though pharmacology has made great strides in the past decade, though we are well acquainted with the physiological action, and even with the therapeutic value of drugs, yet, compared with the vast amount of labor already expended, how small, on the whole, is our success in combating disease by pharmaceutical agents.

I have selected *obesity* as a topic for discussion to-night, because it seems to me that it is a subject upon which some definite and accurate knowledge is already at hand. Knowledge which may be called scientific, because, if the necessary conditions which it imposes be fulfilled, it will enable us to predict what will happen with a certain and, indeed, not inconsiderable degree of success.

Physiological chemistry—great as are the triumphs already achieved—is still in its infancy. And while much that we now think we know regarding the processes of nutrition and of waste will, in the future, be revised or even cast aside, yet sufficient data regarding obesity seem to have been now obtained to justify a basis of action.

In order to gain an intelligent insight into the nature of obesity, it is necessary to have, at least, a general idea of the laws relating to the processes of nutrition.

The body has often been likened to a machine. The food being the fuel, whose consumption becomes manifest in the liberation of energy, of work. But with this difference: that in the body the food is not only the source of energy, but that it also replaces the tissues which are necessarily consumed during the expression of this energy.

Hence, while in the machine only one kind of food—fuel—is needed, whose oxidation produces heat, and that motion; for the body, foods are needed which not only serve the purpose of liberating energy by being oxidized, but which also are capable of being transformed into integral parts of the constantly wasting and constantly growing bodily machine itself. Consequently, we may distinguish two kinds of foods, or, rather, two functionally different foods—"fuel foods" and "tissue foods."

Of the chemical changes going on in the body, it may be said that they consist in general of decompositions and oxidations. In consequence of these processes, relatively complex, slightly oxidized, and hence unstable compounds are converted into relatively simple, highly oxidized, and therefore stable bodies. For example, the relatively complex albuminous, saccharine, and fatty substances are changed mainly into the far simpler compounds, urea, water, and carbon dioxide.

And, concomitant with these changes of chemical form, we have latent energy liberated, whose freedom, becoming potentially manifest, expresses itself in all those various phenomena—muscular contractility, animal heat, nerve action, secretion—which, in their totality, make up that which we term life.

The various articles which compose our dietary may be almost endlessly extended in number. Yet they can be brought into one of three classes, namely: 1. Nitrogenous, albuminous, or proteid foods. 2. Carbohydrates, or starches and sugars. 3. Hydrocarbons, or fats.

Experience has shown that under ordinary circumstances, and in the temperate zone, health is best preserved when the diet consists of a combination of all three of these classes. No fixed amounts applicable to every person and to all conditions can be given regarding the absolute quantity to be ingested, for the measure of food required will vary as circumstances arise which require the expenditure of much or little energy. But it has been found that, on an average, 130 grammes of albumen (equivalent to 1½ pounds of meat), 84 grammes of fat (3 ounces), and 404 grammes (13 ounces) of carbohydrates are consumed daily, and that the proportion of the albuminous to the non-albuminous foods ingested is about 1 to 3¼ or 4.

The study of the causes of the deposition of fat in the body is one of the earliest that engaged the labors of the physiologists, our views having become modified with each increase of knowledge.

After Chevreul, who recently died a centenarian, showed, quite early in the century, that the same substances occur in the fats of animals and of plants, it was thought that deposition was the result of a mere transference from the plant to the body of the excess of fat taken in the food.

The studies of Liebig gradually modified this idea, and it was then believed that the body fat was formed directly from the starches and sugars ingested.

More recently, Pettenkofer and Voit have shown that the albumen of the food is at least the *principal* source of the fat formed in the body. The albumen of the food undergoes, after it has reached the cells of the tissues, certain chemical changes by which part of it is converted into fat, and part goes to the direct nutriment of the tissue cells. According to Voit,* 51·5 grammes of fat can be formed from one hundred grammes of albumen.

Many exact experiments have been made which prove this formation of fat from albumen. Thus, dogs fed on lean meat, and maggots on blood, accumulated considerable fat. A dog fed on lean meat and palm oil, which contains no stearic acid, stored up fat having the usual amount of stearic acid normal to dog's fat.

The fatty degenerations of the organs following phosphorus poisoning, and the fatty condition of the uterus during involution, are familiar instances of fat being one of the decomposition products of albumen.

It is not, however, as though *all* fat were formed from albumen. A *certain amount* of that taken as food is undoubtedly stored up. But the, increase of body fat occurring after eating much fat—though in part a direct result—is chiefly brought about indirectly, the food fat shielding from oxidation that which has been formed from the albumen ingested.

Thus, when a dog is fed on meat and mutton suet, it gains in body fat. Not because the mutton suet is changed into dog's fat, or is deposited as suet, but because the more ready oxidation of the suet prevents the fat proper to the animal's tissues from being destroyed.

It is in the same indirect way that the carbohydrates act. Ordinarily the starches and sugars are not themselves converted into fat. Only when taken in abnormally large quantities does this seem to occur. But when taken as food, along with albumen, they, being more easily oxidizable than the tissue fat, by preventing the latter from being consumed, give rise to an accumulation.

To sum up—we see that there are three sources from which fat may be derived for the body: First, from that resulting from the splitting up of the albumen of the food; second, from the transfer of that fat ingested as food; and third, probably from fat formed from starches and sugars when these are taken in large quantities.

Now, having seen the sources from which the body manufactures its fat, it next remains to inquire into the conditions under which this fat tends to be hoarded up in the tissues of the economy.

Up to quite recent times it was the general belief that the oxygen taken into the blood from the inhaled air was the direct factor concerned in the many chemical decompositions going on in the body. And, in consonance with this view, it was held that fat accumulated from more of it being formed than the oxygen could consume; either excess of food supply or deficiency of oxidation being ascribed as the causes of obesity.

But, alas! seductively simple as this hypothesis appeared, and satisfactorily as it seemed to account for many of the conditions whose existence it was called upon to explain, it has had—like so many plausible explanations—to be relegated to the limbo of errors. It is but another example of the observation to which all of us must have been often led, namely, that the most obvious and plausible explanations of natural phenomena are also almost invariably incorrect. Indirection seems to be a basic principle in the operation of natural law—evolution furnishing its most magnificent example.

Following on the lines first laid down by Rudolf Virchow, that the cell is the somatic unit, we now know that all the metabolic phenomena of the economy have their seat in the cells; that all cells have inherent in them the power of splitting up relatively complex chemical compounds into bodies of simpler composition. And while we are as yet unaware of the processes by which the cell effects these decompositions, we *do* know that the oxygen in the tissues is but indirectly concerned in them. The body being but an aggregation of cells, other things being equal, the more cells an organism contains, the greater will be the amount of chemical change performed.

Certain external agencies have the power of modifying the chemical powers of the cells. Among those that diminish may be instanced quinine, alcohol, morphine, low temperature, and deficient food supply (including oxygen), while excess of food supply, the changes consequent to fever, high temperature, and muscular activity increase them.

Now, the disintegrability of the different classes of foods brought to the cells varies widely, and the causes of obesity, and its treatment on physiological grounds, can only be fully understood when these differences are known and given their due value.

Experiments have shown that of the three great classes of food—the proteids, the carbohydrates, and the hydrocarbons—the one most easily split up is that of the proteids. The carbohydrates are next in ease of decomposition, while the fats are most resistant.

If proteid food alone be ingested, the soluble albumen carried to the cells is there, in part, converted into the tissue albumen of the organ formed of the cells, and in part changed into fat and other products. All of which will tend to be split up into still simpler bodies till the power of the cells becomes exhausted.

If, now, in addition to proteids, fat be ingested, the decomposition of the proteids will go on as before, but the food fat, being more readily oxidizable than the tissue fat formed from the proteids, will shield the tissue fat from destruction, and, at the same time, preserve the tissue albumen from destruction as well.

Thus indirectly, and in a double way, the food fat leads to a storing up of fat. First, by affording a more easily oxidizable substance for the liberation of energy than tissue fat; and, secondly, by preserving the tissue albumen from destruction there results greater chemical activity of the cells, more active elaboration of the food albumen, and, as a result, both increased growth of the cells and increased manufacture and storage of the fat made from the albumen brought to them.

An analogous process obtains when the carbohydrates, in their soluble form of glucose, are fed to the cells together with albumen. The sugar is more easily decomposed than the fat, and may, if present in sufficient quantities, so absorb the energies of the cells as to shield the cells and the fat from destruction, and thus give rise to an accumulation of the latter.

Rubner, working in Voit's laboratory, has determined that the following quantities of the food classes are equivalents—are *isodynamic*, as Voit terms it—that is, that in their decomposition into carbonic acid and water each yields an equal quantity of energy measured by heat:

Fat	100	grammes.
Albumen	211	"
Starch	232	"
Cane sugar	234	"
Glucose	256	"

Now, it will be apparent, from an examination of this table, that an accumulation of fat will most readily occur when the diet contains an overplus of fat, because, while least in quantity, fat has the highest equivalent; next, when containing an overplus of albumen, and next of carbohydrates.

Suppose an individual required per day, to keep his fat and flesh unchanged,* 118 grammes of albumen and 259 grammes of fat, 118 grammes of albumen being equal to 18 ounces of meat.

Were he to take albumen alone, he would require per day 664 grammes of albumen to retain a constant weight. This amount represents six pounds of meat per day, a quantity impossible to consume, the intestinal canal being unequal to the task of digesting and absorbing so large an amount.

Were he still to take the original 118 grammes of albumen, and exclude all fat, 600 grammes—or 1¼ pound—of starch would have to be taken at the same time.

On a mixed diet of all three classes of food, he would take: 118 grammes of albumen, 100 grammes of fat, and 368 grammes of starch.

Any excess in any one of these three classes—supposing, of course, that the mode of life remains unchanged—must lead to an accumulation of fat in the body.

Now, ordinarily, of course, no man habitually eats meals composed either of any one, or even of any two of these food classes. But his diet will consist of the usual combination of all three. And while, therefore, it could hardly happen that an overplus of fat would form even were an individual confined to any two of these classes—for lack of appetite from too monotonous a diet would prevent it, if nothing else did—it can very well happen that on a mixed diet containing plenty of fat and starches, a little more albumen than is needed to maintain the equilibrium of flesh and fat may be ingested.

And it is the fat formed in the cells from this surplus albumen which—since it is protected from oxidation by the food fat and starches—accumulates little by little in the tissues, and gradually leads to obesity.

A man need not necessarily be a glutton to grow stout. It is the slight excess that may daily be taken in the food, which by a gradual increment stores up the fat in the tissues. Nor would even this be sufficient in all individuals. Certain contributory causes often exert a powerful influence in the genesis of obesity, and when these, from any reason, come into play an individual may grow fat, though, as he will tell you, he eats even less than formerly.

Anything which lowers the oxidizing powers of the cells will have this effect, such as free use of alcohol, lack of exercise, living in close, hot rooms, a diet whose insufficiency in albumen lowers the vital powers of the cells, various pathological conditions, such as heart disease and other causes of impaired circulation, chlorosis, etc.

And then—and to this cause the most marked cases of obesity are certainly chiefly due—we must not forget that some individuals have a predisposition, seemingly inborn and often inherited, to grow fat.

It is a fault of the cells, analogous to those aberrations which in some persons produce more uric acid than is normal, which in others lead to glycosuria and diabetes, and in others, again, to the production of cystin. Other individuals, no matter how much they may eat and how little they may exercise, never grow fat.

These same peculiarities show themselves in animals as well as in man. Who ever saw a fat greyhound or a lean pug dog?

Hence, in treating obesity the individuality of the patient must be kept well in mind. In general, we are inclined to associate with fatness a certain indolence of mind as well as of body, an inclination to be unenergetic and phlegmatic—as Prince Henry says to Falstaff: "Thou art so fat-witted with drinking of old sack, and unbuttoning thee after supper, and sleeping upon benches after noon." And yet it may well be

* Read before the Section on Theory and Practice of Medicine of the New York Academy of Medicine, January 21, 1890.

* Voit: Ursachen der Fettablagerung. Munchen, 1864.

* Voit: Ursachen der Fettablagerung. Munchen, 1864.

questioned whether these qualities are not the effect rather than the cause of obesity. Many instances might be cited of stout men being the contrary in disposition. Two of the most shining examples of intellectual industry and acumen that now occur to me were very stout men, Gibbon and Buckle.

Nevertheless, we are inclined to associate leanness with a nervous, keen, and intellectual temperament, activity of mind seemingly going most often with a condition allowing of activity of body. Shakespeare illustrates this popular feeling when he lets Cæsar say to Antony:

"Let me have men about me that are fat;
Sleek-headed men, and such as sleep o' nights;
Yond' Cassius has a lean and hungry look;
He thinks too much; such men are dangerous."

Having now reviewed the chief factors concerned in the manufacture and disposition of fat in the body, the means to be adopted for preventing an accumulation will have become evident.

Our aim must be to make the production not exceed the consumption, and where a surplus exists, consumption must for a time exceed production.

In the great majority of cases (in spite of the protestations of fat people to the contrary), ingestion of too great a quantity, or of an improper quality, of food, often combined with too little exercise, is the cause of obesity.

It remains, therefore, for us to suitably regulate the diet and exercise, bearing in mind that the change we wish to bring about, to be beneficent, must be gradual; that the cells must be educated by degrees to the new duties we wish them to perform; that anything approaching starvation—like the Banting cure—is to be condemned.

With regard to diet, it must be our general plan to give much albumen and relatively little non-nitrogenous food. And we do this in order, first, that the cells from the abundance of nourishment brought to them shall be capable of great chemical activity; and, secondly, that the tissue fat thus necessarily formed shall not be preserved from oxidation by the presence of the more readily oxidizable food fat and starches.

But we must always keep in mind that, as the fat of the body becomes by this process gradually reduced, the diet must undergo a corresponding change, more and more of the non-nitrogenous foods being allowed as the body grows relatively richer in albumen and poorer in fat. For, unless this be done, a point will be reached where not only the fat of the body, but the albumen as well, will be consumed, and the patient, after feeding thus on his own muscular and glandular tissues, will begin to complain of weakness and lassitude.

This is the error of the Banting cure, prescribed to Banting by Dr. Harvey, of London. Banting himself says he had to discontinue treatment every little while in order to regain strength. The Banting diet prescribes enormous quantities of albumen, with an almost total exclusion of fats and carbohydrates. As before stated, it is impossible for a human being to take sufficient meat, eggs, etc., to cover the destruction of fat necessarily occurring, hence the muscular tissues soon begin to waste as well.

Voit gives the following quantities as required for nourishment without the accumulation of fat:

	Albumen.	Fat.	Carbohydrates.	Fat Equivalent.
For a hearty workman	118	56	500	678
For a well-to-do doctor	127	80	362	576

And Oertel,* who has, as you know, given the subject the closest of study, gives the following minimum and maximum amounts per day for reducing fat:

	Albumen.	Fat.	Carbohydrates.	Fat Equivalent.
Minimum	156	22	72	127
Maximum	170	44	114	173

In accordance with these figures he has prepared two diet lists, and the following diet list is one that I have made up as an average of his two, and also somewhat modified for American habits. But I must beg of you to bear in mind that such a list is only to serve as a *general guide* to the patient to whom it is to be given. No absolutely hard and fast rules can be laid down, and patients under treatment should be seen—and weighed—from time to time, increasing one kind of food and diminishing another as soon as occasion demands.

DIET LIST FOR REDUCING FAT.—*Breakfast.*—One cup (6 oz.) tea or coffee, with milk and sugar. Bread, 2½ oz. (2 or 3 slices). Butter, ½ oz. One egg or 1½ oz. meat.

Dinner.—Meat or fish, 7 oz. Green vegetables, 2 oz. (spinach, cabbage, string beans, asparagus, tomatoes, beet tops, etc.) Farinaceous dishes, 3½ oz. (potatoes, rice, hominy, macaroni, etc.), or these may be omitted and a corresponding amount of green vegetables substituted. Salad with plain dressing, 1 oz. Fruit, 3½ oz. Water, sparingly.

Supper or Lunch.—Two eggs, or lean meat, 5 oz. Salad (radishes, pickles, etc.), ¾ oz. Bread, ¾ oz. (1 slice). Fruit, 3½ oz. Or fruit may be omitted and bread, 2 oz., substituted. Fluids (tea, coffee, etc.), 8 oz. No beer, ale, cider, champagne, sweet wines, and spirits. Claret and hock in great moderation. Milk, except as an addition to tea or coffee, only occasionally. Eat no rich gravies, and nothing fried.

Remember that your patients should always feel *better*—never worse—under treatment. That lassitude and fatigue are signs that the muscular tissue, as well as the fat, is being reduced, and that more non-nitrogenous food must then be allowed.

Above all, never yield to the wishes of the patient to grow thin *quickly*. All reforms to be lasting and beneficial must be slow in action, they must be the result of education, they must be a growth from within, not an impress from without. And the cells of the body, in their infinite diversity of occupation resembling the citizens of a state, can by slow degrees be habituated to better things, to change their vicious mode of action to one harmonious with the welfare of the commonwealth, and when this education has once been established, continuance becomes a mere habit.

In all that has been said, no allusion has been made to that form of obesity connected with heart disease. I have preferred to confine myself in this paper to the pure, uncomplicated type, hoping, perhaps, that in the discussion that may follow, this phase of the subject may be dealt with.

In conclusion, let me say that the ideas underlying this sketch of the physiological basis of the treatment of obesity have been taken from the writings of Voit, of Oertel, of Munk and Uffelmann, of Ebstein, and of others.

* M. J. Oertel: Kreislaufs-Storungen, Leipzig, 1885.

EIGHT RAINBOWS SEEN AT THE SAME TIME.

THE following letter, which I have just received from Dr. Percival Frost, of Cambridge, may interest your readers.

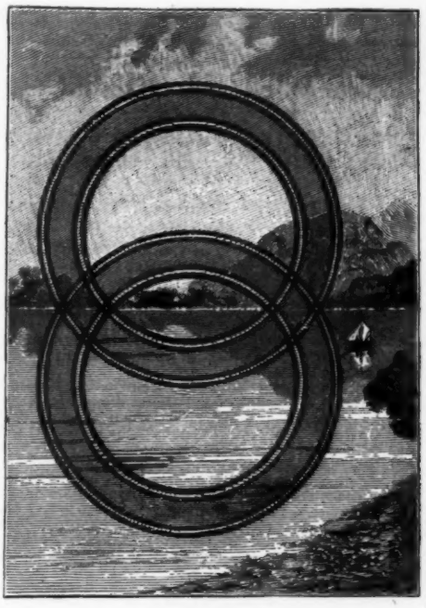
A statement that rainbows are produced not only by the sun itself directly, but by the image of the sun reflected from still water, is given in Prof. Tait's book on "Light." The phenomenon seems to have been observed by Halley in 1698 (see *Nature*, vol. x., pp. 437, 460, and 483, for interesting correspondence on the subject).

The diffuse rainbow produced by the image of the sun reflected from a white cloud after sunset, described by Mr. Scouller, is, I believe, a novelty.

WILLIAM THOMSON.

The University, Glasgow, January 31.

In *Nature* (January 23, p. 271) you give a letter from Mr. Scouller describing an interesting case of a rainbow, due to the image of the sun in water, which, with the ordinary, primary, and secondary bows, make up (there being no secondary to that formed by the reflected sun) the *three* which he saw. Here is a short account of what I saw long ago, almost in prehistoric times, in Scotland, where such sights ought, according to your correspondent, to be very commonly seen. I may mention that I saw at the same time, lasting some five minutes, *eight* well defined rainbows of one sort or another.



In 1841, during the time of a long vacation party, spent at Oban, I walked out with my brother to Dunstaffnage, and we were on the top of the castle, somewhere between 3 and 4 P. M., on a day in the middle of August. Not a breath of wind, bright sun over, I think, Lismore Lighthouse, dusky clouds all over Ben Cruachan and Conoll Ferry; the sea in the bay (bounded by Dunstaffnage in the west) as smooth as a pond. Gradually there appeared before us the astonishing sight of the aforesaid *eight* distinct rainbows, viz., primary and secondary ordinary bows; primary and secondary bows by reflected sun; primary and secondary bows formed by light from the real sun reflected from the water after leaving certain drops; primary and secondary formed by light from the sun reflected at the water, and, after leaving certain other drops, again reflected at the water. I have called the latter four distinct bows, because, although they looked like reflections of a solid set of four arcs, they were really formed by means of drops distinct from those which helped to make the first four bows. I append a sketch of what I saw. PERCIVAL FROST.

15 Fitzwilliam street, January 29.

[We have received other letters on the subject of Mr. Scouller's letter.]—*Nature.*

CONSTITUTION OF CELESTIAL SPACE.

By Prof. DE VOLSON WOOD.

IN a personal letter to the writer some months since, M. Hirn stated that he differed radically from myself in regard to the character of the medium of stellar space. Hirn's work has now been published and an analysis of it has been given in *Engineering* and the SCIENTIFIC AMERICAN SUPPLEMENT. The novelty of the subject, the high standing of its author as a scientist, and his peculiar views as set forth in this work combine to give to the book a special interest. I desire to notice some of the points which have been made in the above analysis.

Some years since I prepared an article upon the so-called "Luminiferous Ether," which was published in the *Philosophical Magazine*, November, 1885, and republished, with additions, in Van Nostrand's Science Series, No. 85. The original article closed thus: "We conclude, then, that a medium whose density is such that a volume of it is equal to about twenty volumes of the earth would weigh a pound (or be equal to one pound of mass), and whose tension is such that the pressure on a square mile would be about one pound, and whose specific heat is such that it would require as much heat to raise the temperature of one pound of it 1° Fah. as it would to raise about 2,300,000,000 tons of water the same amount, will satisfy the requirements of nature in being able to transmit a wave of light or heat 186,300 miles per second, and transmit 133 foot pounds of heat energy from the sun to the earth each second per square foot of surface normally exposed, and also be everywhere practically non-resisting and sensibly uniform in temperature, density, and elasticity—this substance we call the luminiferous ether."

The above properties of the interstellar medium were founded upon the three hypotheses:

1. That the medium transmits a wave with the velocity of 186,300 miles per second, being the velocity with which light is propagated. This is scarcely an hypothesis. It is a fact, the value having been determined with a high degree of precision.

2. That 133 foot pounds of heat energy per square foot of section is transmitted from the sun to the earth in one second. This is not hypothetical, its value having been determined by Professor Langley with such precision as to be probably within from four to six per cent. of absolute accuracy.

3. That the medium possesses the properties of perfect gases. This is hypothetical, but the wave theory of light having been established, the inference that the medium is essentially gaseous in its nature is so natural that one is almost forced to accept it; and will not reject it unless the hypothesis leads to results which are incredible or which are shown to be erroneous either by direct observation or as inferences deduced from data.

It is true that the results are hypermundane, or rather hyperethereal; but so also are the observed results of its energy. Take, for instance, the velocity of a wave, 186,300 miles per second. The length of a wave being $\frac{1}{36800}$ of an inch, each particle of the medium must make $590,000,000,000,000$ (6×10^{14} nearly) complete cycles of movement in a second. Although this number far transcends the powers of the mind to comprehend, yet it is none the less a reality, being the results of accurate measurements. The number of complete cyclical movements of air in the fundamental C is only 264; hence the number of such movements in the stellar medium in transmitting light is about $2,000,000,000,000$ times that in air transmitting sound.

The result of this investigation was to make known to us a medium having definite properties, consistently related to each other, and interfering less with the known economy of nature than any other medium or agent with which we have to deal.

What does M. Hirn propose as a substitute for this medium? He proposes a medium having *a name* without properties. He calls the medium "the dynamic element." We quote from the analysis above given: "This agent is not corporeal, it is an intermediary agent, to which we may give the name of dynamic element. And this element is an objective physical reality, quite as much as the element of matter." The above is a literal quotation from Hirn's work. We would call attention to the fact that it is called a *physical* reality. He would have us believe that there are *physical* realities not material, that there is something between matter and spirit that is a *physical* reality. But we will not press this point. In speaking of something which we believe to exist, but about whose properties we know nothing, it is necessary to use terms with which we are familiar, giving to such terms new meanings.

The analysis says further: "The author does not decide the question how the dynamic element, taken as a whole, acts upon the element of matter, nor does he seek to determine the constituent essence and being of these two elements."

"He contents himself with verifying their existence from a scientific point of view, without making any demand upon our credulity."

"The dynamic element fills infinite space," etc.

M. Hirn's objection to considering the dynamic element as matter in any sense, however rarefied, is the fact that it would offer a resistance to the motion of the heavenly bodies, and thus tend toward the destruction of the systems. He says:

"If a fluid, however rarefied, existed in the infinite space which encircles the heavenly bodies, it would offer some resistance to the movements of the stars in their orbits, and in the process of time the progress of the celestial bodies would be affected by it. With some of them, indeed, such changes of motion could be verified by observation extending over several centuries. On our earth, this acceleration of its revolution would have the result of shortening the year. For if one kilogramme of matter were diffused in 8,600 cubic kilometers, it alone would in 2,000 years diminish the length of the sidereal year by five seconds and alter the longitude by 205 seconds."

While we admit the general argument, we do not understand why M. Hirn used these particular figures. The mass of the "dynamic element" here assumed to occupy a given volume exceeds immensely the mass assigned to it by any modern writer of which we have knowledge since the days of Herschel and Young. Our analysis gives one pound to twenty volumes of the earth, that is one pound to about $72,000,000,000,000,000,000,000$ cubic feet (72×10^{21}).

One kilogramme being about 2·2 pounds, and one cubic kilogramme being $(3,280)^3$ cubic feet $=35,300,000,000=35\times10^9$ cubic feet nearly.

And hence 8,600 cubic kilometers is 3×10^{14} nearly cubic feet, and one pound would occupy 14×10^{12} nearly cubic feet. This would be about 50,000,000 times as dense as the ether found by our analysis. So that if the dynamic element resisted in proportion to its density, it would require 100 trillions of years to diminish the sidereal day by five seconds, assuming that Hirn's computation is correct. Such an infinitesimal diminu-

tion will elude observation if made during the entire range of history.

If this slight diminution be not sufficient to satisfy any philosopher of its practical non-resisting property, we have only to apply the method of reasoning of M. Hirn in regard to the loss of heat of the sun. He says: "The explications which have been hitherto given to account for solar radiation are inadequate. Everything tends to show that the sun has been receiving from some source yet unknown a quantity of heat equal to the amount it loses by radiation, since the time when, by studying its definite mean temperature, we assume that this process might have begun."

The argument appears to be, no diminution of heat has been detected, therefore it is supplied from an unknown source. If it is easy to admit this, how much easier is it to admit that no diminution in the revolution of the planets having been detected, therefore their energy has been maintained from some unknown source. When La Place found that the force of gravitation, if propagated by an elastic medium, must have a velocity exceeding 100 million times that of light, concluded that astronomers might continue to consider its action as instantaneous (*Mech. Celeste*, b. x., ch. viii., p. 22, 9,035). A medium that is resisting the motion of the earth at such a rate as would require more than a trillion million of years to destroy its energy may be considered as non-resisting. This assumes that the entire mass of the medium in the track of the earth is given a velocity equal to that of the earth; and Professor Michelson has shown that the ether at the earth has no perceptible velocity in reference to the earth. It appears to be carried along with the earth.

On one important point it appears to me that Hirn's arguments are self-contradictory. He says: "If the upper strata of the terrestrial atmosphere, which are carried round with the earth as it rotates, are already in exceedingly rapid motion, met with any resistance, however slight, they would be checked and lag behind the planet in its course, and would finally be irretrievably lost in space. The continued existence of the planetary atmosphere is absolutely irreconcilable with the presence of gas of any kind in space."

Here the particles of air are supposed to be drawn away from the earth on account of the presence of a medium, while in the case of the moon the latter would ultimately fall upon the earth, on account of the presence of the same medium. In one case it would force matter away from the earth, while in the other it would cause matter to be drawn to the earth. The same reasoning applied to the moon would result in the conclusion that the medium would "cause it to lag behind the planet in its course, and would finally be irretrievably lost in space." Such a conclusion is known to be erroneous. Applying the reasoning to the atmosphere, and it simply follows that the attraction of the earth for a particle of air in the upper strata exceeds the resistance of the medium. In my memoir, referred to above, I considered this question, and found that the attraction of the earth for a molecule of air exceeded the resistance of the medium considered by more than 100,000 times, so that the outer particles of our atmosphere are held by the earth more rigidly than is the moon in its orbit. A medium as dense as the hypothetical one assumed by Hirn would produce the disastrous effects assigned to it, and is, therefore, fatal; but this does not warrant the assertion made, that the slightest resistance would drag the atmosphere away from the earth and scatter it irretrievably into space.

Much of the force of Hirn's reasoning lies in the fact that he has assumed, for his argument against a corporeal medium, a density of a million times that found by simple rational hypotheses. As a further argument he says: "As a consequence of the pressure produced by the motion of the moon, the gaseous medium would attain the enormous temperature of 38,280 deg. C." The analysis giving no intimation how this result is reached; the text probably does. But we know that pressure alone cannot determine the result, a knowledge of the specific heat of the medium being necessary.

This I considered in my memoir, and found for the medium which I considered that the specific heat exceeded 4,600,000,000,000, that of water being unity; and, according to the assumption made by Hirn of the temperature of space, it would be several times as large as this value. Now, the temperature of the medium which we investigated would not be increased by a small fraction of one degree by the pressure caused by the motion of the moon. Indeed, the temperature of the medium would not be increased unless it were condensed, and we assume that the amount of condensation to which it is possible to subject it in space is inconceivably small. We will be curious to see the argument by which M. Hirn reached his conclusion.

While Encke and his contemporaries in astronomy concluded that the motion of Encke's comet indicated, if not proved, the resistance of a medium, modern analysis has shown that all its perturbations may be accounted for by other known causes—at least within the limits of the errors of observation. This question I also considered in my memoir, and showed that the energy of a comet in the medium I discussed would not be destroyed in a million million years; so that if it had any effect upon the motion of a comet, it could not be detected by observation within historic times. The physics of the cometary bodies is too imperfectly known to warrant any sweeping conclusions in regard to them

What is the force of the question, "The temperature of space devoid of matter"? If there is no *matter*, can there be temperature? What is the nature of that medium which will transmit thirty calories of heat per minute per square meter at the earth without itself having some temperature—however small? If celestial space has any temperature, is it not filled with something having some property akin to matter? May it not be true that the "dynamic element" is identical with the somewhat familiar "luminiferous ether"? True, M. Hirn denies the "corporeal" nature of the former, but may not the hyper-qualities of the latter be so far removed—or above—our ideas of gross matter as to supply all the properties necessary for the office of the former? Our medium is destitute of weight in the sense that repulsion equals attraction; it, however, has *mass*, or the vanishing value of mass—it is very slightly "corporeal."

For our part we prefer the medium which we investigated to the "non-corporeal dynamic element;" the former satisfying, as it does, *almost perfectly* every condition demanded of it in the economy of nature and conforming in its action to well known laws, while the latter, existing from absolute necessity, but without even assumed physical properties or acting without known or assumed laws.

Nearly all the investigations upon the physics of nature indicate a dissipation of energy and, hence, a termination of the present order of things. The mind seems to cling, instinctively, to an eternal life, to an endless continuation of the present order of the physical universe, and for this reason seeks for the possible restoration of energy to supply wastes. Thus, the energy of the sun is being wasted—so far as its own condition is concerned—by supplying heat to other worlds, and, if this law be continued without compensation, the time will come, however remote, when its heat energy will all have been expended, and become of the temperature of the medium in which it exists. To avoid this catastrophe different hypotheses have been resorted to, but they in turn have a limited life. In our memoir we stated that if the specific heat of the sun were the same as that of the ethereal medium as determined by us, it would continue to give out heat at the present rate for untold ages without becoming perceptibly cooler. Many of the substances in the sun are known to exist on the earth, and it is impossible to say whether any substance exists in the sun having a hyper-specific heat.

The easiest way to manage the question is to relegate it to the realms of *faith*—as Hirn has done—by assuming that its heat energy is constant, and, therefore, that it receives its heat from an unknown source, but this is not science.

Certain writers, not many years since, explained certain phenomena upon the earth by assuming that the earth passed through a portion of space which was hotter than the average; but our theory maintains that the temperature of space is almost exactly uniform.

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